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Exploring the impact of metaverse adoption on sustainability outcomes in retail organizations: A dynamic capabilities view perspective

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ABSTRACT

The metaverse presents an opportunity for retailers' sustainability in how its value can be created with efficient resources, inclusivity, and less waste. Nevertheless, the relationship between metaverse adoption and sustainability outcomes is not sufficiently explored in the literature. Building on the Dynamic Capability View (DCV) and employing a two-study mixed method approach, it is examined how metaverse adoption affects the economic, environmental, and social aspects of sustainability performance, emphasizing the role of technology infrastructure. A qualitative study (Study 1) based on interviews' thematic analysis revealed that metaverse-enabled dynamic capabilities of collaboration, business process optimization, realignment with stakeholders' empowerment, and pro-environmental practices are key mediators in this relationship, whereas technological infrastructure shapes these dynamic capabilities. A quantitative approach (Study 2) using PLS-SEM provided empirical support for Study 1. The findings suggest that collaboration enhances social and environmental sustainability; business process optimization enhances economic sustainability; stakeholder empowerment enhances economic, social, and environmental sustainability; and pro-environment practices enhance economic and environmental sustainability. Furthermore, technology infrastructure strongly moderates the relationship between metaverse adoption and dynamic capabilities, including collaboration, stakeholder empowerment, and pro-environmental practices. Finally the study yields a strategic roadmap for the retail sector to harmonize innovation with long-term sustainability objectives.

1. Introduction

The business environment is swiftly transforming due to two primary factors: a transition to an information-driven economic model and an increase in digitization across several sectors (Abumalloh et al., 2023). The transformation instigated by disruptive technologies like blockchain (BCT), artificial intelligence (AI), and extended reality (XR) mirrors the revolutionary influence of the Internet era, altering industry and consumer behavior (Barrera and Shah, 2023; Yoo et al., 2023). Especially in retail, these technologies significantly impact customer choices, as it provides immersive, interactive, and personalized shopping experiences that address the increasing need for convenience and innovation (Yoo et al., 2023). The metaverse, a convergence of augmented and virtual reality (AR/VR), BCT and digital ecosystems, serves as a revolutionary platform set to reshape industrial paradigms (Koohang et al., 2023; Richter and Richter, 2023). The metaverse enables immersive interactions and novel business models by merging virtual and physical realities, signifying a transition from conventional e-commerce to virtual commerce (Kar and Varsha, 2023). This transition offers unprecedented opportunities for customer engagement, operational efficiency, and sustainability, particularly in consumer-facing industries like retail.

As an industry with significant direct consumer engagement, retail possesses a unique advantage by nature of its reliance on consumer preference to apply these technological advancements (Chen et al., 2023; Koohang et al., 2023). A quick transition to digital transformation during the pandemic emphasized that all businesses need appropriate flexible strategies. Another thing is, within this context, the metaverse has emerged as a strong and adaptive environment for developing innovations (Barrera and Shah, 2023). Simultaneously, there is mounting pressure on retailers to integrate their operations with sustainability objectives (Go and Kang, 2023). This advancement highlights the pivotal role of the retail sector in addressing sustainability challenges while reinforcing the need for it to compete in a rapidly transforming digital ecosystem (Dwivedi et al., 2022).

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Sustainability in this context, is a multi-dimensional concept encompassing three key dimensions: economic, environmental, and social pillars. Economic sustainability refers to strategies that ensure long-term profitability while fostering innovation and resilience within markets (Kumar and Shankar, 2024). In the metaverse context, this involves developing virtual economies, flexible work models, and new revenue opportunities (Pamucar et al., 2022, 2023; Dwivedi et al., 2022). For example, the metaverse enables businesses to transform conventional economic models by creating virtual marketplaces, facilitating direct-to-avatar transactions, and promoting digital entrepreneurship (Deveci et al., 2022; Koohang et al., 2023). Nevertheless, challenges persist, including high investment demands for technological infrastructure, increased energy consumption, and market volatility associated with digital assets, all of which may threaten economic sustainability (Dwivedi et al., 2022). However, existing literature remains focused on conceptual approaches, signaling the need for empirical research to substantiate these observations (Koohang et al., 2023).

Environmental sustainability, centered on the conservation of resources, reduction of carbon emissions, and minimization of ecological footprints, is one of the more debated aspects of metaverse adoption (Kumar and Shankar, 2024). Advocates highlight its potential to enhance resource efficiency by reducing the need for physical offices, business travel, and traditional production processes (Abumalloh et al., 2023). For example, virtual collaboration tools, digital twins, and immersive simulations allow businesses to streamline operations and reduce environmental waste (Deveci et al., 2022; Pamucar et al., 2022). Retailers can harness these tools to develop sustainable supply chains and lower emissions, thereby aligning with international sustainability objectives (Dwivedi et al., 2022). However, critics point out the metaverse's energy-intensive nature and dependency on data centers, which could amplify its environmental footprint (Chen et al., 2023). Furthermore, the incorporation of BCT for secure transactions and ownership tracking risks contributing to e-waste and heightened carbon emissions (Kshetri and Dwivedi, 2023).

Social sustainability emphasizes building equitable, inclusive, and cohesive societies. The metaverse holds significant potential in this area, offering tools to democratize opportunities, bridge geographic divides, and promote digital inclusion (Rajguru and Brüggemann, 2024). Examples include virtual job fairs, educational programs, and immersive social spaces that empower underserved communities and enable broader participation in economic activities (Kar and Varsha, 2023; Al-Emran, 2023). The metaverse's capacity to replicate real-world scenarios also presents novel opportunities for skills training and collaborative initiatives (Dincelli and Yayla, 2022). However, the social impact of metaverse adoption is multifaceted. While it enhances connectivity, it introduces risks related to mental health, digital dependency, and data privacy (Arpaci et al., 2022). Furthermore, the immersive nature of metaverse platforms could exacerbate inequalities if access remains limited to technologically advanced regions, potentially leading to social isolation for less privileged groups (Abumalloh et al., 2023). For industries like retail, addressing these challenges is critical to fostering consumer trust, ensuring inclusivity, and balancing innovation with ethical responsibility (Eggenschwiler et al., 2024).

Despite the increasing interest in the metaverse as a transformative platform and its potential alignment with sustainability objectives, significant gaps persist in the existing body of knowledge. Although current research emphasizes the metaverse's potential to transform consumer experiences through immersive and interactive technologies (Chen et al., 2023), there is insufficient investigation into how these innovations can be strategically utilized to tackle urgent sustainability issues in the retail industry. While much of the literature focuses on technology feasibility and customer behavior (Dwivedi et al., 2022; Richter and Richter, 2023), the impact on environmental and social sustainability remains fragmented and inadequately explored. Existing literature mostly emphasizes the economic aspects of the metaverse, resulting in considerable deficiencies in comprehending its wider sustainability implications (Go and Kang, 2023; Umar, 2022). The inconsistencies in current academic discussions regarding the metaverse's influence on environmental and social sustainability highlight the need for a comprehensive analysis to reconcile conflicting viewpoints. This study thus aims to answer the following research questions: *RQ1: What is the metaverse's impact on economic, environmental, and social sustainability? RQ2: What is the underlying mechanism through which the metaverse influences the three dimensions of sustainability?*

However, integration of the metaverse depends heavily on the technological preparedness of the digital ecosystem (Kumar et al., 2023). Given the convergence of augmented and virtual reality (AR/VR), AI, and high-speed connectivity, robust technological infrastructure is essential (Far et al., 2023). Technological infrastructure, including essential systems like hardware, software, network connectivity, and data management platforms (Dwivedi et al., 2022; Kumar et al., 2023; Fainshmidt et al., 2016), facilitates the core functionalities of the metaverse and serves as a boundary condition that influences the degree to which metaverse adoption affects organizational processes (Koohang et al., 2023). Robust infrastructure guarantees essential components such as minimal latency, rapid connectivity, immersive experiences, and secure data management through BCT (Wamba-Taguimdje et al., 2020), which are vital for fostering capabilities that enhance organizational adaptability and innovation (Mikalef et al., 2021). Conversely, companies with insufficient infrastructure may encounter issues like as inefficiencies, disruptions, and diminished scalability (Kumar et al., 2023), hindering their capacity to fully exploit the potential of the metaverse. Given these insights, our study further investigates: *RQ3: How does technology infrastructure moderate the relationship between metaverse adoption and dynamic capabilities?*

Drawing on the Dynamic Capability View (DCV), the primary objective is to clarify how metaverse adoption enhances a firm's sustainability (Teece et al., 1997). The DCV is a critical theoretical framework that underscores an organization's ability to integrate, reconfigure, and adapt its resources in response to rapidly changing environments (Teece, 2007). In contrast to static capabilities, DCV emphasizes the importance of dynamic, forward-looking processes such as sensing opportunities, seizing them, and transforming internal capabilities (Teece, 2014). In the context of metaverse adoption, DCV is particularly relevant as it provides insights into how firms can leverage emerging technologies to drive sustainability by fostering innovation, efficiency, and strategic flexibility (Zabel et al., 2023).

The study contributes to existing literature in several significant ways. Firstly, it addresses inconsistencies comprehensively and empirically regarding the metaverse's impact on sustainability pillars, a novel approach in the field. Secondly, it fills a notable gap by integrating environmental and social dimensions alongside economic aspects in metaverse analysis. Thirdly, it extends and refines the DCV framework to incorporate metaverse challenges and opportunities, especially in the retail sector. Lastly, it explores technology infrastructure as a boundary condition, enriching the understanding of effective metaverse adoption contexts. The structure of the remainder of this paper is as follows: Section 2 reviews the pertinent literature and establishes the theoretical foundation of the study. Section 3 describes the research methodology, including hypothesis formulation and the analysis of findings. Section 4 engages in a comprehensive discussion of the results, articulating both theoretical and practical contributions, and concludes by highlighting the limitations and outlining avenues for future research.

2. Literature review and theoretical framework

2.1. What do we mean by Metaverse?

The term "Metaverse" was originally used by Neal Stephenson in his novel Snow Crash which was written in 1992 and is a combination of the Greek word "meta" meaning "beyond" with the word "universe" and refers to a massive virtual reality space where users are represented by avatars. The early more outdated views from the 1990s viewed it as an elaborate 3D space for avatar-oriented navigation and usage, has developed into a highly integrated system of virtual reality spaces. However, a common definition has not been developed, and it is understood in various ways, from social networks to the connected digital environments (Buhalis et al., 2023). The scholars have offered various definitions for it including the immersive virtual world defined by Davis et al. (2009) and the one compared with the World Wide Web by Goldberg and Schär (2023). According to Kar and Varsha (2023), it is a socio-economic system that is built on digital interactions. Dwivedi et al. (2022) consider it as the parallel existence of real world in virtual mode. Yoo et al. (2023) stress on the immersive shared spaces and Barrera and Shah (2023) define metaverse as the scalable extended reality environments which include both the physical and the virtual worlds (p. 6). In the same way, Park and Lim (2023) of the metaverse as a system of three-dimensional virtual environments for humans' interactions and cultures, which has such characteristics as realism, persistence, and interoperability. Despite the variations in the understanding of the metaverse, it can be noted that it is characterized by the ability to perform various functions, interoperability, and provides users with rich immersive experiences according to Buhalis et al. (2023); it provides users with an opportunity to engage in various activities within a simulated real-life environment (Davis et al., 2009).

One of the key features of the metaverse is its decentralized nature which is basically anchored on the use of blockchain technology (BCT). While conventional centralized systems are controlled and managed by a single authority, the decentralized system of the metaverse improves on the aspect of trust, transparency, and security since power is shared by the participants (Dwivedi et al., 2022). Decentralization in the metaverse transcends structural modifications to democratize resource access and decision-making processes. Decentralized autonomous organizations (DAOs) function as essential governance structures, allowing users to collectively design platform regulations, content moderation guidelines, and resource distribution techniques (Dolgui and Ivanov, 2023). This interactive method corresponds with the metaverse's fundamental concept of user empowerment, enabling participants to exert increased control over their digital experiences (Goldberg and Schär, 2023). BCT is the technology that supports data ownership and privacy, two fundamental elements leading to trust formation in the metaverse platforms (Tan and Saraniemi, 2023). On the other hand, centralized systems have proven to be vulnerable to identity fraud and data breaches; thus, BCT allows users to own their data and digital properties, restricting unauthorized access and utilization (Huynh-The et al., 2023). This feature effectively tackles these fundamental privacy and security concerns, creating a more secure environment (Aysan et al., 2024). Another benefit of the decentralized architecture of the metaverse is the ability to support interoperability (Chen et al., 2023). The use of BCT standards makes it possible for users to move their avatars, NFTs and virtual currencies from one metaverse to another (Koohang et al., 2023; Dwivedi et al., 2022). It also improves user participation as it creates a unified and integrated virtual environment, but at the same time, it also helps in the growth of the metaverse in terms of the number of users and activities. Nevertheless, decentralization has its problems. BCTs, including those that use proof-of-work protocol, have received flak for being detrimental to the environment because of the former's energy consumption (Pereira et al., 2019). Current approaches, including the proof-of-stake algorithms and layer-2 technologies, are mitigating these problems by enhancing BCT effectiveness and decreasing the carbon footprint (Rajguru and Brüggemann, 2024).

2.2. Metaverse and retailing

The metaverse has garnered significant scholarly attention across various disciplines for some years. To our knowledge, this area of investigation has thus far been examined solely within the domains of information technology, marketing, education, tourism, and psychology (e.g., Barrera and Shah, 2023; Buhalis et al., 2023; Far et al., 2023; Go and Kang, 2023). Initially, discussions focused on theoretical dimensions, conceptualizing it as an advanced Internet integrating BCT, digital assets, and avatars (Dwivedi et al., 2022).

While research on the metaverse is increasing, particularly in marketing, it remains in its infancy, notably with advertising, luxury, retail, sales, and branding (Dwivedi et al., 2022). A substantial body of scholarship has examined consumer behavior in virtual retail environments enabled by the metaverse (Eggenschwiler et al., 2024). Research exists on user-avatar relationships (Kim et al., 2023) and the correlation between social consumption and emotional states (Choi et al., 2023). Park and Lim (2023) established a framework to evaluate the effects of NFTs on brand equity and consumer interaction experiences, providing fashion brands entering the virtual realm with critical insights by examining brand equity transfer through new technology (NFTs) and brand experience in digital contexts. Yoo et al. (2023) elucidate the metaverse as an advancing technology and a significant facilitator of product enablement, suggesting opportunities for further exploration in metaverse-enabled retailing.

The metaverse has been attractive to consumers due to the immersive shopping experience and special interactivity it brings (Dincelli and Yayla, 2022; Yoo et al., 2023). Metaverse retailing encourages interaction between companies and their customers as it allows for virtual demonstrations, collaborative shopping habits, and user-generated content (Barrera and Shah, 2023). Furthermore, the metaverse's 3D environment alters consumers' perception of services compared to traditional 2D environments (Hadi et al., 2024). The metaverse serves as a new-age technological paradigm in retailing, a virtual space that allows consumers to shop beyond the physical, forming a direct connection with retailers. Previous studies (Queiroz et al., 2023) suggest that industries would experience improved operational and resource efficiency, energy efficiency, innovative capabilities, agility, and improved collaboration upon adopting the metaverse as a potential opportunity. Although several researchers have explored the nexus between the metaverse and sustainability, numerous studies are confined to theoretical or conceptual frameworks (Dwivedi et al., 2022; Koohang et al., 2023). Pamucar et al. (2022) demonstrate the potential effects of the metaverse on sustainable transportation in terms of virtual twin frameworks for optimizing shared mobility and lowering emission rates. Umar (2022) also suggested that it could trigger the achievement of Sustainable Development Goals (SDGs) by solving key global issues with the help of modern technologies like BCT, AI, AR, and VR. Such actions include the introduction of virtual consultation services and wider e-learning platforms for medical professionals as well as e-administration systems in urban and rural regions, contributing to Goal 3 (Healthcare Access). In a similar vein, Goal 4 (Inclusive Education) has the potential to thrive with AR/VR technologies that build immersive, accessible learning environments that are built to cater to the diverse needs of all learners, especially those with disabilities. However, its impact on sustainable performance remains ambiguous (Arpaci et al., 2022; Abumalloh et al., 2023).

Koohang et al. (2023) examine the implications of economic sustainability on the economy, encompassing consumer experience and marketing techniques. Arpaci et al. (2022) investigate its ramifications for societal sustainability, emphasizing psychological and social dimensions. The discussion on the societal implications of the metaverse is highly heated in the current literature (Al-Emran, 2023). Nevertheless, little attention has been paid to the metaverse's effect on environmental sustainability. While some argue that the metaverse reduces energy consumption by enabling virtual activities (Al-Emran, 2023), others suggest that its high technological demands lead to increased energy usage and a greater carbon footprint (Abumalloh et al., 2023). Kshetri and Dwivedi (2023) examine the consequences of pollution reduction and energy consumption reduction while emphasizing the ambiguous long-term equilibrium between the two. Although there is increasing interest in the metaverse's potential in social, economic, and environmental spheres, the current study predominantly focuses on its effects on consumer behavior (Richter and Richter, 2023), while sustainability issues remain largely unexamined (Abumalloh et al., 2023). While Al-Emran (2023) examines the metaverse's impact on economic, environmental, and social sustainability, the discussion lacks clarity and methodological rigor. In this context, Klaus and Manthiou (2024) advocate for future studies to explore the uncharted domains concerning the environmental and societal impacts of the metaverse. In the same manner, Eggenschwiler et al. (2024) emphasize the need for further research in order to gain a better insight into the environmental consequences of metaverse retailing. Abumalloh et al. (2023) emphasize that the retail sector notably lacks comprehensive empirical research on the sustainability implications of metaverse adoption. Therefore, the present research aims to contribute to filling this gap by analyzing how metaverse dynamics are connected with sustainability objectives so as to develop a more solid theoretical framework that would include the issues of economic feasibility, environmental effects, and social justice.

2.3. *Dynamic capability view*

Teece et al. (1997) introduced the Dynamic Capability View (DCV) to underscore firms' adaptability in dynamic environments. Teece's (2007) definition of dynamic capabilities (DCs), emphasizing sensing, seizing opportunities, and maintaining competitiveness, is widely accepted. These capabilities are crucial in digital transformation, improving decision-making and restructuring. Contrary to ordinary or zero-level capabilities that facilitate routine operations, efficiency, and incremental enhancements (Winter, 2003), DCs represent advanced capabilities that facilitate intentional and strategic transformation, protecting against imitation (Teece, 2007; Kamble et al., 2021; Matarazzo et al., 2021). Ordinary capabilities allow organizations to "do things right," whereas dynamic capabilities enable firms to "do the right things" by aligning resources with changing opportunities and threats (Teece, 2014). The primary difference between ordinary and dynamic capabilities pertains to their nature, scope, and function. Ordinary capabilities preserve the status quo and are additive, reproducible, and predominantly unchanging, focused on enhancing established practices (Zollo and Winter, 2002). Their performance is frequently quantifiable via cost reduction or productivity indicators and typically assists the firm in "operating the business" (Helfat and Winter, 2011). DCs pertain to altering the existing state of affairs (Teece, 2014). These capacities frequently encompass ambiguity and implicit knowledge, are more challenging to codify, and are integrated within organizational processes and learning routines (Zollo and Winter, 2002). They assist the company with "renewing or reinventing the business" by facilitating innovation, market realignment, and long-term adaptation (Teece, 2014).

The literature also suggests that while ordinary capabilities can be acquired or outsourced, developing DCs requires focused internal effort (Helfat and Winter, 2011; Teece, 2007, 2014). The DCV framework posits that a firm's competitive advantage stems from its ability to dynamically adjust, evolve, and rejuvenate assets to meet market demands (Teece et al., 1997). This theory emphasizes organizational processes in amalgamating skills to navigate change (Teece, 2007; Teece, 2014). The Resource-Based View (RBV) utilizes distinctive resources for competitive advantage but faces criticism for its static methodology (Bromiley and Rau, 2016). Conversely, DCV emphasizes the strategic significance of dynamic skills in responding to environmental changes (Teece et al., 1997). DCV is especially applicable in volatile environments, highlighting the necessity for ongoing adaptation (Schilke, 2014), which is crucial for sustaining competitiveness (Teece, 2007).

The current research shows that DCs have effects on organizational performance, innovation, and strategic outcomes in the presence of technological changes and a competitive environment. For instance, Dangelico et al. (2017) found that certain DCs are crucial for large manufacturing firms, including the DCs for resource building and reconfiguration, which have positive effects on market performance. Mohaghegh et al. (2021) stress the necessity of higher-order DCS, such as agile manufacturing and continuous improvement for sustainable development. In digital business ecosystems, DCs are crucial for addressing change, co-opetition, network dynamics, and platform orchestration (Zabel et al., 2023). The literature analyzes the vital importance of dynamic capabilities in advancing sustainability objectives. DC aids organizations in integrating economic, environmental, and social dimensions into their strategies, fostering innovation and alignment with evolving stakeholder expectations (Eikelenboom and de Jong, 2019; Kumar et al., 2018). By incorporating sustainability into organizational processes, firms can use green technologies, adopt circular economy ideas, and enhance sustainable supply chain management (SSCM). For instance, Mathivathanan et al. (2017) explored how dynamic capabilities, when developed through SSCM practices, can lead to improved organizational performance with tangible sustainability benefits. Buzzao and Rizzi (2021) introduced a layered framework for sustainability-focused DCs, showing how these can be both measured and embedded across various dimensions of sustainability. Tiberius et al. (2021) examined family-owned businesses and shed light on microfoundations like future orientation, tradition mindset, fast decision making, resource slack, innovation mindset, investment in human capital and greater participation can drive economic resilience and social responsibility.

Building on the foundational understanding of DCs, emerging technologies have been recognized as pivotal enablers that amplify the effectiveness of DCs in dynamic and complex environments. For example, Kamble et al. (2021) identify BCT as a critical enabler of sustainable supply chain performance through its capacity to foster integration and enhance transparency. Felsberger et al. (2022) similarly underscore the significance of digital transformation in improving DCs that facilitate the connection between technical innovation and sustainability results. These technologies equip organizations with the means to enhance operations, minimize inefficiencies, and synchronize operational goals with environmental and social imperatives, thus reconciling technological adoption with sustainability objectives.

The application of the DCV to the metaverse represents a promising yet underexplored area of research. With its rapidly evolving digital ecosystem, the metaverse necessitates continuous adaptation, strategic agility, and resource reconfiguration: core tenets of DCs. Dolgui and Ivanov (2023) highlight the integration of cyber-physical systems and digital twins as enablers of supply chain resilience and agility in the metaverse. The metaverse's transformative potential, however, extends beyond agility and resource reconfiguration. It offers opportunities to address challenges such as interoperability, and immersive customer engagement (Zabel et al., 2023). While early studies suggest the metaverse can reduce environmental impacts through virtual activities and foster inclusivity, there is a lack of research on how firms can align their resources in a way that will allow firms to pursue sustainability and innovation strategies that are compatible with the metaverse. This dual focus remains important in realizing the potential of the metaverse while also complying with the tenets of sustainability.

Therefore, we propose that DCV is a suitable theoretical framework to assess the metaverse effect on sustainable retail performance, which involves the economic, environmental, and social sustainability goals in the retail processes. Firstly, the metaverse is a hub of technological innovation, driving new business models (Dwivedi et al., 2022) and aligning with DCV's focus on adapting to dynamic environments (Teece, 2007, 2014). Secondly, DCV's emphasis on DCs allows for exploring how metaverse tech enables firms to innovate sustainably. Lastly, the metaverse adds market uncertainty, underscoring DCV's relevance in volatile contexts (Fainshmidt et al., 2016; Schilke, 2014).

3. Research design

The research employs an exploratory sequential mixed-method approach, as advocated by Venkatesh et al. (2013), to support theory development and evaluation, integrating qualitative and quantitative methodologies. This methodology is considered effective for comprehending intricate phenomena and human perception (Creswell and Clark, 2017; Zhao et al., 2024), especially in exploratory investigations. Mixed methods facilitate the creation of an extensive conceptual framework and methodological triangulation, hence improving the generalizability of qualitative findings through quantitative validation (Creswell and Clark, 2017).

The mixed-method technique in social science research is esteemed for mitigating survey response biases (Dincelli and Yayla, 2022; Podsakoff et al., 2003) and enhancing the generalizability of results, hence preventing anomalies associated with single studies (Zhao et al., 2024). This approach suits this study due to the nascent state of the metaverse concept and the lack of empirical validation regarding its impact on sustainability (Richter and Richter, 2023; Arpaci et al., 2022; Koohang et al., 2023). Aligned with Venkatesh et al. (2013) recommendation, this study adopts an exploratory sequential mixed-method design to ensure both theory development and empirical validation. In order to investigate how metaverse adoption affects sustainability outcomes in the retail industry, the study is organized into two interrelated phases. In Study 1, we employ a qualitative approach and identify important metaverse-enabled DCs through thematic analysis of expert interviews. The DCV was used as the theoretical framework that guided the interpretation of these themes. It explained how businesses adjust and reorganize their resources in digitally transformational environments and led to the development of six key propositions and the conceptual model for the study. Study 2 was then built on the analysis of Study 1 and quantitatively operationalized and tested the relationships between metaverse adoption, dynamic capabilities, and sustainability outcomes using Partial Least Squares Structural Equation Modeling. This sequential design allowed the qualitative findings to directly shape the development of testable hypotheses, which were then empirically examined through PLS-SEM in the second phase, ensuring that the theory was not only conceptually sound but also statistically validated.

3.1. Study 1: Qualitative study and proposition development

3.1.1. Data collection

In the first stage, the study utilizes qualitative research via semi-structured interviews, which are particularly effective for investigating new and intricate phenomena. This approach guarantees the acquisition of varied viewpoints while providing the flexibility for subsequent inquiries, so enhancing the depth and comprehensiveness of the data (Yin, 2009). Semi-structured interviews depend on participant responses, following an interview guide (See Appendix 1) that includes the preliminary questions to be asked during the interviews.

Given the complexity of the study's subject matter, expertise from both the metaverse technologies and retail industry domains was crucial for a thorough analysis. To access hard-to-reach respondents, a combination of theoretical and snowball sampling was used (Gillani et al., 2024). LinkedIn was initially utilized, following Baruffaldi et al.'s (2017) guidelines, using targeted keywords including "Metaverse," "Augmented reality," "Virtual reality," "Extended reality," "Mixed Reality," and "Retail." This ensured that the sample is particularly appropriate given the study's focus on examining the DCs and sustainability outcomes associated with metaverse adoption. The diversity of professional roles ensured the capture of multidimensional insights, encompassing strategic vision, technological innovation, and practical implementation. Similarly, the cross-industry representation allowed for a broader understanding of the metaverse's applicability and implications beyond a single sector. The high level of professional experience added depth and rigor, as participants could draw on practical knowledge and expertise. From 50 initial outreach attempts, 14 positive responses were received. Subsequently, respondents were asked to refer others from their networks, facilitating snowball sampling. This method ensured access to individuals not easily reached by traditional sampling. The combination of these methods enabled gathering reliable responses from a targeted pool of experts, ensuring comprehensive analysis. We decided upon the sample size based on the concept of theoretical saturation, which is the point when additional data does not yield new themes, insights dimensions, or properties to the evolving framework (Glaser and Strauss, 2017; Saunders et al., 2018). This was the main criterion that led to the end of data collection. This aligns with the definition of saturation as the point of conceptual completeness, rather than simple data repetition (Saunders et al., 2018). Our approach also finds empirical support in Guest et al. (2006), who pointed out that many qualitative studies reach saturation within the first twelve interviews. Likewise, Tiberius et al. (2021) demonstrated that even a relatively small number of interviews (eleven interviews with leaders of family businesses in the case of their study) yield valuable and credible findings, especially when the participants are carefully selected and information-rich. This gave us confidence to stop data collection once we noticed that no new themes were emerging. In total, 22 interviews were performed, with an average of 37 min per interview. Data collection was concluded when no additional significant insights were likely to be developed from the interviews, and responses started to be repetitive and redundant, indicating the attainment of theoretical saturation. Participants were assured anonymity to mitigate social desirability bias and assigned codes from R1 to R22 (See Table 1 for respondent profile summary).

3.1.2. Data analysis

The interviews were transcribed within a strict twelve-hour timeframe to ensure high recall, following Yin's (2009) recommendation. Initially, the interviews focused on exploring metaverse-enhanced capabilities for firms, followed by discussions on their implications for economic, environmental, and social sustainability in retail. The analysis of the qualitative data followed a dual-method approach, integrating Braun and Clarke's (2006) thematic analysis with Dubois and Gadde's (2002) systematic combining. This combination ensured both a systematic exploration of the data and a theoretically grounded refinement of the findings. Initially, Braun and Clarke's six-phase framework guided the thematic analysis. The process began with familiarization, during which the 329 pages of transcripts were thoroughly reviewed to identify recurring ideas and patterns. Subsequently, initial codes were developed to capture specific insights, such as "virtual collaboration enhances decision-making" and "real-time tracking reduces environmental waste." These codes were systematically organized into broader themes, including collaboration, business process optimization, stakeholder empowerment, and pro-environmental practices.

Following the thematic analysis, Dubois and Gadde's systematic combining was employed to refine the theoretical framework using abductive reasoning iteratively. This process involved moving between the empirical findings and the DCV to ensure the themes were both theoretically and practically relevant. The theme of collaboration was mapped to the DCV due to its critical role in enhancing organizational adaptability.

Similarly, the theme of business process optimization demonstrated the DCV's focus on reconfiguring internal processes to achieve efficiency, innovation, and sustainability. Pro-environmental practices align with the reconfiguration dimension of DCV, which enables organizations to adapt and transform internal resources and processes to meet evolving environmental demands. The theme of stakeholder empowerment emphasized the inclusivity and accessibility enabled by virtual platforms, which fosters organizational agility by leveraging their knowledge, creativity, and participation.

Triangulation was employed to ensure qualitative rigor to minimize the risk of researcher bias (Köhler, 2016). The data was triangulated

Table 1
Respondents' profile.

Respondents	Job Role	Industry	Experience (in years)	Interview duration
R1	Chief Executive Officer	Start-up (Metaverse and Gen AI solutions)	11	33 mins 21 s
R2	Technology consultant (XR, Metaverse)	Software and IT	7	45 mins 35 s
R3	Assistant VP (Digital Marketing and Technology)	Retail	14	37 mins 24 s
R4	Data Science Leader	Software and IT	15	40 mins 13 s
R5	Business development and customer success manager	Retail	13	44 mins 24 s
R6	Assistant Manager (Digital Marketing and Technology)	*E*-commerce	8	39 mins 03 s
R7	Head (Technology Infrastructure & Security)	Retail	18	35 mins 33 s
R8	Senior enterprise architect (Emerging technologies)	Software and IT	21	36 mins 28 s
R9	Senior technical manager (AR/VR)	Software and IT	14	32 mins 27 s
R10	Assistant Director (Emerging Technologies)	Consulting	16	39 mins 25 s
R11	Associate Manager (Growth and Partnerships)	Retail	9	43 mins 38 s
R12	Senior Product Manager	Technology services and solutions	17	32 mins 34 s
R13	Solution Architect (Metaverse, IoT, Digital Twin)	Software and IT	19	38 mins 33 s
R14	Senior product manager	Manufacturing (AR, VR products)	11	44 mins 13 s
R15	Chief Technology Officer	Retail	19	32 mins 25 s
R16	Vice President (Retail technology)	Retail	21	31 mins 13 s
R17	AR/VR Developer	Consulting	9	46 mins 22 s
R18	Project Consultant (AR/VR solutions)	Consulting	7	43 mins 44 s
R19	Head (Emerging technology and innovation center)	Software and IT	23	37 mins 13 s
R20	Chief Digital and Marketing Officer	Retail	24	34 mins 21 s
R21	Senior Software Engineer (AR/VR)	Software and IT	8	40 mins 22 s
R22	Emerging technologies leader (AR/VR)	Manufacturing	14	45 mins 26 s

using secondary sources from both practice, as well as academic literature to support credibility (Eisenhardt, 1989; Lincoln & Guba, 1988). The respondent's consistency of responses at different intervals was analyzed for reliability. An example of a response from Respondent 6 is presented in Table 1 (Validity in Appendix 2a and Reliability in Appendix 2b).

3.1.3. Study 1 data analysis

The qualitative interviews show that the metaverse ecosystem enables four DCs for firms, which are collaboration, business process optimization, stakeholder empowerment, and pro-environmental practices that have a significant impact on the sustainable performance of the firms across the economic, environmental, and social dimensions. We contend that these capabilities should be categorized as DCs rather than ordinary capabilities because of their transformational, adaptable, and strategic characteristics in unstable contexts (Teece, 2014). Contrary to maintaining the status quo, they reorganize organizational resources, processes, and relationships to adapt to the evolving requirements of sustainable operations inside the firm (Bag et al., 2022; Buzzao and Rizzi, 2021; Randhawa et al., 2021; Tiberius et al., 2021; Zabel et al., 2023). In the metaverse ecosystem, these four capabilities demonstrate distinctly transformational and adaptable characteristics.

In this context, collaboration extends beyond conventional coordination across departments or partners. It entails the co-creation of immersive digital environments, the development of interoperable systems, and the establishment of strategic alliances across both real and virtual domains. Firms can utilize the metaverse to develop innovative value co-creation frameworks with customers, suppliers, and competitors (Zabel et al., 2023). This illustrates the reorganization of relational and structural capital, which is fundamental to the dynamic capability of assimilating and reconfiguring external resources (Köhler et al., 2022; Kumar et al., 2018; Teece, 2007).

Likewise, business process optimization within the metaverse encompasses more than only enhancing efficiency. It allows companies to transform core operations using immersive technology like digital twins, virtual simulations, and AI-driven interactions (Samadhiya et al., 2024). These technologies provide real-time experimentation, design, and adaptation, enabling organizations to not only achieve incremental improvements but also to fundamentally re-engineer business models and workflows (Chen et al., 2023; Samadhiya et al., 2024). This corresponds with the "seizing" and "transforming" dimensions of dynamic capacities, wherein organizations extract value from opportunities by modifying internal operations (Chirumalla, 2021; Felsberger et al., 2022; Ghosh et al., 2022). The metaverse-driven process optimization functions at a strategic, transformative level, consistent with the definition of DCs.

Stakeholder empowerment signifies a transformative change in governance and engagement (Helfat and Peteraf, 2003; Shafieisabet and Haratifard, 2020). Blockchain and decentralized autonomous organizations facilitate enhanced transparency, involvement, and value co-creation with stakeholders, such as customers, communities, and employees (Mačiulienė and Skaržauskienė, 2021). This capability signifies the reorganization of organizational roles and decision-making authority, enabling organizations to enhance their agility and responsiveness to stakeholder requirements (Ortiz-Avram et al., 2024), a hallmark of dynamic reconfiguration (Fainshmidt et al., 2016; Schilke, 2014). Conventional stakeholder engagement methods are typically linear and reactive (Loureiro et al., 2020; Passetti et al., 2019). The metaverse provides immersive tools that facilitate interactive, participative, and real-time engagement of stakeholders in strategy formulation, product development, and decision-making (Dolgui and Ivanov, 2023; Koohang et al., 2023). This capability transforms the manner in which businesses manage and collaboratively generate value with external entities, allowing the firm to reorganize its external relationships and institutional structures. From a dynamic capabilities perspective, stakeholder empowerment illustrates transformative actions that modify the organization's engagement and value delivery strategies (Helfat and Peteraf, 2003), thus promoting organizational agility and innovation through improved alignment (Ortiz-Avram et al., 2024; Zabel et al., 2023).

Lastly, pro-environmental practices enabled by the metaverse, such as reducing physical resource use, substituting virtual for physical prototyping or events, and promoting sustainable digital consumption (Deveci et al., 2022; Kumar and Shankar, 2024; Pamucar et al., 2022) go beyond compliance. The capability of pro-environmental practices signify a strategic transformation of the firm's environmental footprint and production logic. Firms using the metaverse to advance sustainability objectives are embedding environmental values into their dynamic sensing and transforming processes (Abumalloh et al., 2023; Zabel et al., 2023), thereby reshaping their long-term value-creation mechanisms in line with environmental sustainability (Ortiz-Avram et al., 2024). Pro-environmental practices in this study go beyond compliance or efficiency gains and act as a strategic, future-oriented capability rather than a static or routine function."

Regarding collaboration, experts note the metaverse's capacity to redefine traditional norms, fostering an environment where joint decision-making and inclusive participation are not just encouraged but deeply embedded. Virtual environments overcome geographical and temporal constraints, enabling diverse perspectives to enhance decision-making. This inclusive participation fosters innovation, driving collaborative efforts towards innovative solutions in product design, strategic marketing, and operational efficiency.

The analysis indicates that the metaverse equips firms with real-time tracking, monitoring, and simulation capabilities, facilitating close examination and refinement of business processes for optimization. Experts assert that metaverse-enabled empowerment surpasses conventional boundaries, offering scalable access and promoting a culture of digital literacy and virtual training. This empowerment guarantees equitable participation chances irrespective of geographic location or socioeconomic background, fostering innovation and ongoing learning. Furthermore, the metaverse acts as a stimulus for environmentally sustainable practices through strategic initiatives such as customization, regenerative funding mechanisms, and advocacy for circular design. These efforts aim to minimize waste, promote sustainable consumption, and align with environmental goals.

The analysis further reveals that technology infrastructure serves as a crucial factor influencing the effectiveness of the metaverse in enabling DCs. Industry experts emphasize that robust technology infrastructure can enhance the metaverse's impact on DCs like collaboration, stakeholder empowerment, pro-environmental practices, and business process optimization. Advanced infrastructure enables seamless integration of metaverse functionalities, ensuring reliability and efficiency in leveraging these capabilities for collaboration, empowerment, sustainability, and process optimization.

The distinction between technology infrastructure as a moderator and DCs as mediators arises from their fundamentally different roles in organizational processes. Technological infrastructure is essential, providing the flexibility, integration, and connectivity required to implement strategic procedures (Lu et al., 2021). As a steady contextual facilitator, it enhances or limits relationships among organizational elements, influencing the environment for strategic endeavors (Mikalef et al., 2021). Informed by modular systems theory, infrastructure promotes scalability and responsiveness, enabling firms to adapt dynamically to changes without disrupting core systems (Wamba-Taguimdje et al., 2020). Its principal function is to augment the efficacy of other resources rather than directly influencing performance (Lu et al., 2021).

Conversely, DCs, distinguished by their iterative and adaptive characteristics, are ideally positioned as mediators. These skills connect external inputs to performance results by converting enabling situations into actionable strategies (Felsberger et al., 2022). Based on absorptive capacity theory, they enable knowledge assimilation and resource exploitation, acting as operational mechanisms that transform infrastructure potential into competitive advantages (Arranz et al., 2020). From this perspective, infrastructure represents the "what" (resources), while DCs represent the "how" (processes) (Felsberger et al., 2022). This alignment is consistent with the DCV, which posits that capabilities transform resources into performance outcomes while adapting to contextual factors (Teece, 2007). Thus, positioning technology infrastructure as a moderator and DCs as mediators is both theoretically and empirically justified. These findings, supported by thematic analysis, are detailed in Appendices 3, 4, and 5. Anchored in the DCV theoretical lens, which acts as the guiding framework and qualitative data, six propositions have been formulated and illustrated in Fig. 1, laying the foundation for subsequent quantitative testing employing partial least squares structural equation modeling in the next stage of research.

Note: To assess the details of themes, subthemes, and narratives, please refer to Appendix 3–5.

3.1.4. Research model and proposition development

3.1.4.1. The influence of metaverse on the dynamic capabilities of the firm. Originally viewed as a means to improve operational efficiency in stable contexts, technology is now acknowledged in scholarly literature as crucial for organizational adaptation and responsiveness (Gillani et al., 2024). Academics regularly assert that technology adoption, characterized as the proficient use of new technologies, is essential for firms seeking to enhance their dynamic capacities. Ghosh et al. (2022) illustrate how developing technologies facilitate dynamic capacities, propelling digital transformation. Similarly, Quayson et al. (2023) demonstrate how BCT cultivates the dynamic qualities essential for circular economic models. The analysis indicates that the metaverse's characteristics can foster and improve four essential DCs: cooperation, stakeholder empowerment, business process optimization, and pro-environmental practices. Collaboration improves an organization's agility and responsiveness to environmental changes (Buzzao and Rizzi, 2021), which are key dimensions of DCs. Collaboration enables firms to sense opportunities and threats, seize them effectively, and transform processes and resources to maintain a competitive advantage (Khan et al., 2020). In virtual environments, collaboration becomes even more significant as it facilitates the integration of diverse knowledge and expertise within cross-functional teams, enabling real-time innovation and problem-solving (Gillani et al., 2024). Business process optimization aligns closely with the DCV as it entails the reconfiguration of internal processes to achieve efficiency, innovation, and sustainability. The ability to continuously improve and adapt business processes enables firms to respond effectively to dynamic market environments, a core principle of DCV (Teece, 2014). Existing literature provides empirical evidence that digitally enabled process optimization facilitates process innovation by integrating new capabilities, thereby enhancing organizational flexibility and responsiveness to market needs (Chirumalla, 2021). Furthermore, stakeholder empowerment can be categorized as a DC because it enables firms to adapt to changing environments by leveraging stakeholders' knowledge, participation, and resources (Randhawa et al., 2021). This enhances the ability to contribute to explorative and exploitative activities, improving the firm's agility in responding to environmental changes (Ferreira et al., 2020). Lastly, pro-environmental practices can be classified as DCs because they enable firms to sense environmental changes, seize opportunities for sustainability, and reconfigure internal resources and processes to adapt to evolving environmental demands (Khan et al., 2020). Bag et al. (2022)

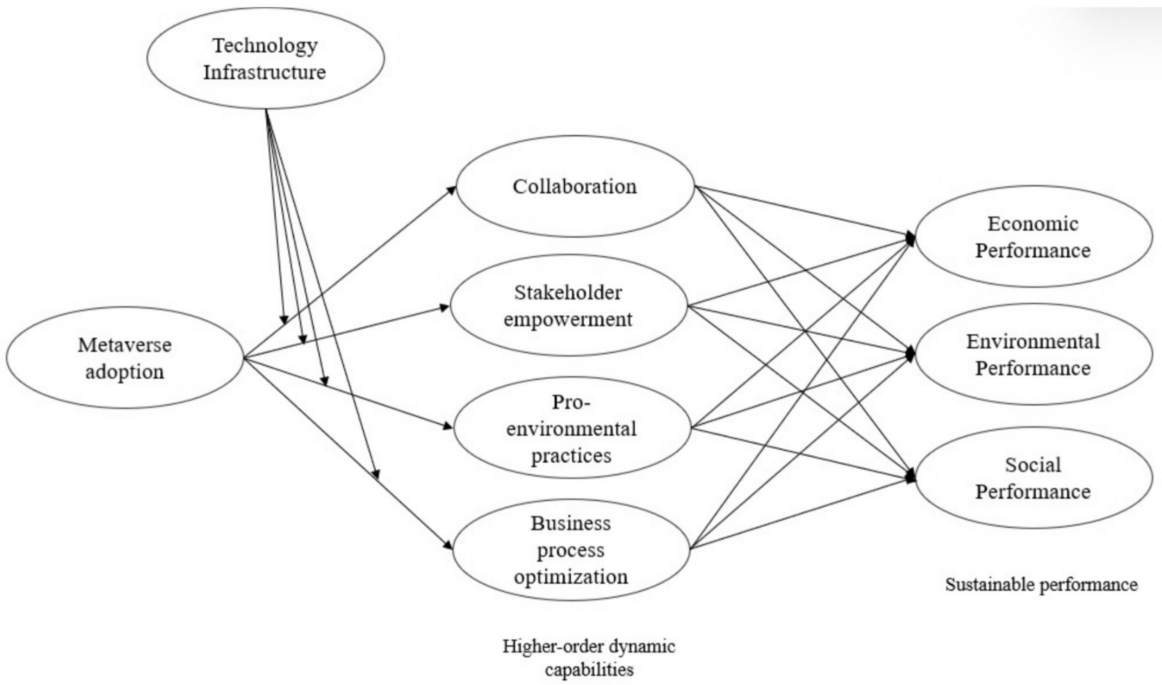

Fig. 1. Conceptual model.

argue that eco-innovation and green supply chain practices; key forms of pro-environmental practices, help firms adapt to changing regulations and stakeholder expectations, reflecting DCs.

The qualitative findings indicate that the immersive characteristics of the metaverse facilitate realistic reproduction and augmentation of real-life interactions in a virtual environment, offering a new method for remote collaboration that surpasses existing video conferencing solutions. This paradigm shift enhances collaborative engagement and stimulates team creativity and invention through the utilization of three-dimensional environments and objects (Buhalis et al., 2023; Koohang et al., 2023). Within this virtual realm, spatial and temporal barriers vanish, enabling real-time gatherings irrespective of geographical distances, thereby promoting cross-functional collaboration and enhancing decision-making processes. Moreover, the metaverse's capacity for real-time data visualization and manipulation promises to revolutionize collaborative analysis, leading to more efficient problem-solving. The scalability and persistence of virtual workspaces in the metaverse provide a flexible environment for collaboration, further enhanced by its tendency towards decentralization, fostering a sense of community and collective ownership facilitated by BCT (Huynh-The et al., 2023). These assertions are underpinned by qualitative findings, as exemplified by one of the respondents who states: *"Collaboration will become much more seamless and inclusive. In traditional meetings, it's easy for certain voices to dominate the conversation or for remote team members to feel disconnected. But in the metaverse, everyone has an equal presence and can actively participate in discussions regardless of their physical location. This has fostered a more democratic and inclusive decision-making culture within our organization. Plus, the immersive nature of the metaverse makes brainstorming sessions more creative and engaging, leading to innovative solutions that we might not have considered otherwise (R17)."*

Experts suggest that firms can achieve enhanced business process optimization through simulated environments, enabling real-time tracking, monitoring, and forecasting. Virtual replicas of business operations enable precise planning and execution, aiding firms in building resilient and adaptable operational frameworks (Dolgui and Ivanov, 2023; Chen and Ruan, 2024). The metaverse offers unprecedented opportunities for efficiency gains and innovation through virtual simulations and digital twins (Zabel et al., 2023). Integration with the Internet of Things (IoT) enables granular tracking and monitoring of operational metrics, facilitating precise identification and resolution of inefficiencies (Zhang et al., 2024). Simulated environments allow risk-free experimentation and optimization of complex operational processes, extending to route optimization and demand forecasting, thereby enhancing operations. Virtual inventory management, automated workflows, and immersive training platforms in the metaverse can significantly streamline operational efficiencies, reducing costs and enhancing employee competencies (Dwivedi et al., 2022). These assertions are underpinned by qualitative findings, as exemplified by one of the respondents who states: *"With this advanced simulation ability, we can proactively see the impact of production delays, supply chain disruptions, demand fluctuations and even beyond that, we can understand the overall impact of using different raw materials in our productions …. So technically, we can ensure that even if disruptions occur, we are continuing the operations and workflow smoothly, minimizing the actual disruption in the real world. Imagine having this during COVID-19. I guess the impact we felt that time would not have happened. We could have managed with fewer losses…. (R22)."*

The decentralization of metaverse platforms, often enabled by BCT, brings transparency and autonomy not typically seen in traditional corporate ecosystems (Goldberg and Schär, 2023). Stakeholders gain greater ownership over digital assets, influence governance, and actively contribute to digital content and services (Dwivedi et al., 2022). This shift to a more participatory model is especially significant for marginalized groups, overcoming traditional barriers to access. The metaverse offers innovative educational and training opportunities, using VR and AR to simulate real-world scenarios and enhance digital literacy (Dwivedi et al., 2022). These capabilities empower stakeholders for success in the digital economy, with global accessibility promoting inclusivity (Koohang et al., 2023). This argument is corroborated by the qualitative finding: "*The metaverse offers a virtual space where geographical barriers and physical limitations are virtually non-existent…… One example I can think of is virtual job fairs and recruitment events. Retailers can host these events in the metaverse, allowing job seekers from around the world to attend without the need for travel. This levels the playing field, giving everyone an equal chance to connect with potential employers and explore job opportunities (R14)*".

Participants highlight the metaverse's impact on encouraging pro-environmental behavior, facilitating responsible consumption, and supporting circular economic concepts. The customization and personalization features in virtual environments facilitate sustainable consumption behaviors, since virtual marketplaces provide made-to-order products to minimize waste (Arpaci et al., 2022). Digital fashion and virtual commodities facilitate self-expression and consumption while mitigating the environmental consequences linked to the manufacture of physical items (Arpaci et al., 2022). Furthermore, the metaverse's simulation of environmental effects and advocacy for regenerative finance projects illustrate its potential as a driver of sustainability (Abumalloh et al., 2023). Through incentivizing sustainable behaviors and facilitating virtual transactions, the metaverse can contribute to environmental mitigation and sustainability promotion (Abumalloh et al., 2023). This argument is corroborated by the qualitative finding: *"See, in the physical world, we are still stuck with linear ways of working, but with metaverse, we can actually promote circular designs by enabling circular economy marketplace. So technically, here we can facilitate the buying, selling, and exchange of pre-owned or refurbished products, which ultimately contribute to a reduction in waste and resource consumption in the real world. …. Now the question is, what is the implication in the real world? When users purchase virtual clothing or accessories for their avatars instead of buying physical items, it reduces the demand for new materials and manufacturing processes, ultimately conserving natural resources such as water, energy, and raw materials (R18)."* Based on the above discussion, we hypothesize:

H1. : Metaverse adoption positively influences the dynamic capabilities of a) collaboration, b) business process optimization, c) stakeholder empowerment, and d) pro-environmental practices.

3.1.4.2. The influence of dynamic capabilities on the economic, environmental, and social sustainability of the firm. Literature recommends transitioning emphasis from direct marketing analytics results to utilizing them for the improvement of distribution centers and overall business performance (Agag et al., 2024). Common capabilities, however advantageous for immediate survival, may fail to maintain a competitive edge or guarantee enduring results (Agag et al., 2024). Given sustainability's recognition as a competitive advantage, firms must cultivate higher-order capabilities to achieve sustainable development in a competitive landscape marked by rapid technological advancements and evolving customer preferences (Mohaghegh et al., 2021).

In this context, insights from industry experts highlight four crucial DCs: collaboration, business process optimization, stakeholder empowerment, and pro-environmental practices as essential drivers of firms' economic, environmental, and social sustainability. Collaboration involves forging networks and partnerships to foster innovation and gain competitive advantage (Ghosh et al., 2022). Business process optimization leverages technology to streamline operations and enhance adaptability (Gillani et al., 2024). Stakeholder empowerment enables engagement and contribution across the value chain (Shafieisabet and Haratifard, 2020). Pro-environmental practices embed sustainability into business operations (Bag et al., 2022).

Collaboration is particularly vital for driving organizational growth and operational efficiency, allowing organizations to reduce costs and enhance competitiveness (Kumar et al., 2018). By pooling resources and expertise, organizations can innovate, streamline processes, and adapt to market shifts. The qualitative finding supports the argument: "*See, no matter how much we go for expert feedback and customer suggestions, we can only reach or access a handful of people; based on their suggestion, we finalize and manufacture the apparel. But understand that even if we only manufacture and produce 10 designs and if they are not what the consumer wants, then that is a waste for the company, right?" (R20).*

Moreover, improved collaborative initiatives are essential in fostering environmental stewardship by consolidating shared knowledge and resources to address ecological issues. Experts assert that virtual environments within the metaverse facilitate collaboration among stakeholders in the creation and testing of waste management techniques. For instance, by simulating the placement of recycling bins and experimenting with signage to encourage recycling, retailers can co-create effective systems that maximize recycling rates and minimize waste in retail spaces. In addition to waste management, virtual prototyping in the metaverse allows suppliers and retailers to collaborate on packaging designs, optimizing materials and configurations to reduce environmental impacts across manufacturing, distribution, and disposal processes. Real-time data visualization and simulation further empower retailers and technology providers to analyze and optimize energy consumption within retail spaces. By identifying inefficiencies and co-developing sustainable solutions, these collaborative efforts lead to substantial reductions in energy use. This argument is supported by the qualitative finding: "*I believe that if we have the capability to collaborate in real-time, a lot of issues can be taken care of proactively, too. From the ideation phase itself, taking with us all the stakeholders, customers, employees, and everyone who is impacted by our business decisions, we can design a product that is sustainable, and the best part about this real-time and virtual collaboration is that not only can we identify the problem areas but work in real-time by leveraging the strengths of all the involved collaborators to mitigate the problems" (R6).*

The experts further highlight that collaboration is crucial in promoting inclusivity by ensuring the representation of diverse perspectives, contributing significantly to social sustainability. Through collaborative initiatives, organizations work towards bridging gaps, guaranteeing equal access to opportunities and resources (Al-Emran, 2023). This collective engagement with social issues leads to the formulation of solutions that are both inclusive and equitable, fostering social cohesion and improving the quality of life for communities at large (Arpaci et al., 2022). This argument is corroborated by the qualitative finding: *"I believe integrating feedback mechanisms into virtual shopping experiences can be a game-changer. It's essentially like having a direct line of communication between the consumer and the manufacturer. This real-time feedback loop allows users to provide input on their preferences, concerns, and suggestions directly to the companies. So if we can find a smoother way through which we can collaborate directly with our customers, it will provide intangible benefits to us by fostering a sense of trust and transparency between the company and our customers. See, when customers feel that their input is being valued and acted upon, it strengthens their connection to the brand and increases their loyalty (R5)"*. In light of the foregoing discussion, we propose the following hypothesis:

H2. : Collaboration enhances the sustainable performance of the firm by positively influencing a) economic, b) environmental, and c) social performance outcomes.

Industry experts emphasize the vital role of business process optimization in enhancing organizations' operational efficiency, effectiveness, and agility. By automating processes, firms can streamline workflows, allocate resources more efficiently, and reduce time and resource requirements for task completion. This optimization not only increases output but also enhances product and service quality, leading to greater customer satisfaction and retention. Business process optimization significantly impacts organizations' economic performance by maximizing resource utilization and minimizing operational redundancies, resulting in cost savings and improved operational agility. This argument finds support from the qualitative finding: *"With increased forecasting abilities and prediction of patterns and trends in the real-time, we can predict more accurately what our consumer wants and do not have to take in thousands of assumptions and trust me no matter how much we assume on historical data things take unexpected turns. So, the underproduction and overproduction of games do not go wrong now. And with these predictions actually, we can also proactively mitigate risks associated with supply chain disruptions, leading to enhanced economic sustainability" (R3)*.

Experts further highlight the critical role of business process optimization in reducing the environmental footprint of organizational activities. By refining operations and adopting sustainable solutions, organizations can effectively minimize waste, conserve resources, and reduce emissions. Real-time monitoring enables organizations to track resource consumption, such as energy and water, and identify waste generation, facilitating immediate corrective actions to mitigate environmental impact. Virtual simulations and digital twins provide risk-free platforms for testing and refining workflows, reducing the need for resource-intensive physical trials and allowing organizations to evaluate the environmental consequences of their operations proactively. Additionally, route and supply chain optimization, supported by real-time data analytics, reduces fuel consumption and emissions by identifying efficient delivery routes. Enhanced forecasting and data analytics ensure accurate demand prediction, preventing over-production and associated inefficiencies. Collectively, these mechanisms align business processes with sustainability goals, promoting resource efficiency, emissions reduction, and environmentally responsible practices. This argument finds support from the qualitative finding: "*The ability to remotely monitor and manage devices and processes through advanced connectivity is a game-changer. It allows for real-time adjustments, minimizing unnecessary energy consumption. Another important feature that I want to highlight here is cloud computing, which enables multiple applications to run on shared infrastructure, reducing the need for individual servers and data centers, and also enables companies to scale their computing resources based on demand, ultimately leading to significant energy savings ….*" *(R2)*.

Qualitative observations underscore the influence of business process optimization on social sustainability, accentuating its importance in promoting equitable workplace practices and facilitating work-life balance. Initiatives to improve efficiency and equity foster more inclusive workplaces, where diversity is esteemed and opportunities are allocated fairly. By prioritizing employee well-being and promoting equitable labor practices, organizations strengthen social frameworks, contributing to societal welfare and fostering cultures of respect and equality. Furthermore, optimizing business processes often involves redesigning roles, offering employees more varied and engaging tasks, and granting greater autonomy. When positions accurately correspond with employees' skills and expectations, individuals find their work more meaningful, resulting in heightened job satisfaction, decreased turnover, and a favorable company culture. This argument is substantiated by the qualitative finding: *"If we have the ability to optimize business processes and streamline the work, we can value the skills and competencies of be it our employees or channel partners and leverage them to achieve greater goals than just merely run after efficiency and cost optimization. In this process what we achieve is that our network feels more valued, respected, and engaged. So if we understand at greater depths optimization is beyond costs and profits it's about treating our human capital right" (R5)*. Based on the above discussion, we hypothesize that:

H3. : Business optimization enhances the sustainable performance of the firm by positively influencing a) economic, b) environmental, and c) social performance outcomes.

Participants highlight the capacity for stakeholder empowerment, especially among employees, to foster innovation inside firms. When stakeholders perceive their worth, they are more inclined to propose ideas that stimulate the development of new products, services, or process enhancements, hence providing firms with a competitive advantage (Shafieisabet and Haratifard, 2020). Empowering customers through feedback solicitation and their involvement in product creation can improve satisfaction and loyalty. This promotes economic sustainability by cultivating trust and loyalty among stakeholders, resulting in enhanced engagement, productivity, innovation, and consumer happiness. Stakeholders' timely feedback on virtual prototypes enables organizations to iterate swiftly and economically, minimizing rework time and resource expenditure. Additionally, involving customers early in virtual product launches aids in accurately gauging demand, minimizing overproduction, and responding swiftly to market trends. This argument is corroborated by the qualitative finding: *"A very big misinterpretation I feel people have about metaverse is that it is going to replace our physical worlds. No, it is not like that at all. Rather, it will function as a lever to enhance our designs, processes, products, and services in the physical world … metaverse can actually help us explain the project or plan to our client and stakeholders more effectively, so time, money, and resources spent on reworking on correcting the miscommunications are all gone, …" (R18)*.

Respondents suggest that stakeholder involvement fosters responsible behaviors aligned with environmental sustainability goals. Empowered stakeholders are more likely to support initiatives reducing carbon footprints, optimizing resources, and enhancing sustainability. They may invest in digital tokens for sustainable projects, yielding financial returns and environmental benefits. Real-time data analytics aid in energy optimization and waste reduction, improving environmental performance metrics. This argument finds its support from the qualitative finding: *"When stakeholders are effectively trained on sustainability practices, it transforms how businesses approach environmental responsibility. Imagine suppliers participating in virtual workshops where they learn ethical sourcing techniques and methods to reduce waste, like water-efficient production processes. These insights can then be directly applied, conserving valuable resources and minimizing environmental harm. This will cultivate into a habit you see that too without any constraint and having a trade-off with the economic implications" (R10)*.

Further, empowering stakeholders to actively engage in organizational decision-making ensures that diverse perspectives are heard and valued. This empowerment fosters a sense of ownership and belonging among stakeholders, enhancing social cohesion and contributing to the resolution of social issues through collective action and shared responsibility. This approach can lead to more creative solutions to social and business challenges, improve employee morale, and enhance the firm's reputation among consumers and potential employees. This argument finds support from the qualitative finding: "…. *Coming from fashion retailing, I believe focusing on inclusivity is very, very important owing to the increased awareness of the consumers regarding the social issue and expecting the firms they are associated with to uphold ethical standards. A unique feature in the metaverse is designing products and experiences that are inclusive and accessible to diverse populations. In the context of apparel manufacturing, this means involving a wide range of stakeholders, including individuals with disabilities, different body types, and cultural backgrounds, in the design process" (R20)*. Our findings echo Tiberius et al. (2021), who emphasize that socially-oriented microfoundations like participation, investment in human capital and innovation culture are essential to achieving sustainability outcomes. In a digital retail context, metaverse tools enable these same participatory mechanisms virtually, thus aligning with broader trends in sustainable capability development. Based on the above discussion, we hypothesize that:

H4. : Stakeholder empowerment enhances the sustainable performance of the firm by positively influencing a) economic, b) environmental, and c) social performance outcomes.

Respondents suggest that adopting pro-environmental practices promotes economic sustainability by aligning organizational operations with sustainability principles. This alignment reduces environmental risks, complies with regulations, and enhances the organization's reputation among environmentally conscious consumers. Implementing green methodologies and technologies, such as energy efficiency and waste minimization, goes beyond compliance and can lead to cost reductions and differentiation in the market (Chen et al., 2023). This strategic shift towards sustainability not only protects the environment but also creates economic opportunities, driving revenue growth through sustainable products and services. This argument finds support from the qualitative finding: *"We have a lot of inspection-related activity, inspecting our own warehouse, suppliers, distributors, and that not only adds to a lot of travel-related costs, but we have to allocate a lot of financial and non-financial resources. So ultimately, that is a cost we are incurring, right? If* *we can implement remote inspection processes using the advanced technologies under the umbrella of metaverse, not only will this be fast and in real-time but we can use the resources we have towards areas that are more strategic in nature …." (R3)*.

Pro-environmental practices play a vital role in embedding sustainability into organizational operations, ranging from resource conservation to embracing circular economy principles. By championing sustainable practices, firms not only contribute to environmental conservation but also drive industry-wide shifts towards sustainability, highlighting the corporate sector's role in environmental stewardship. Innovative approaches like virtual product testing, cloud computing, and smart sensor applications enable organizations to reduce their carbon footprint and environmental impact, aligning with broader sustainability goals. Moreover, strategies such as virtualization and digital transition decrease the need for physical retail infrastructure, thereby reducing energy usage and emissions (Kshetri and Dwivedi, 2023). Additionally, utilizing BCT allows companies to support renewable energy ventures and sustainable initiatives, enhancing their eco-friendly reputation and advocating for a circular economy (Quayson et al., 2023). This argument is corroborated by the qualitative finding: *"Earlier, I talked about regenerative finance initially, right? So we can leverage blockchain technology in the metaverse actually to enhance or improve environmental outcomes. We can create innovative financial mechanisms that support sustainable projects while actively contributing to the regeneration of ecosystems and communities. Now, firms and individuals can purchase digital tokens representing shares in renewable energy infrastructure projects or regenerative initiatives …. Investors can purchase these tokens, enabling them to support sustainable retail initiatives and share in their success" (R20)*. Furthermore, pro-environmental practices, while primarily aimed at environmental preservation, also yield significant social benefits. By embracing sustainable approaches, organizations contribute to community welfare, ensuring cleaner air, water, and natural habitats. These practices often integrate social considerations, such as ethical sourcing and fair trade, directly promoting social equity and justice, thus enhancing societal well-being. They enhance a firm's social performance by demonstrating a commitment to societal values. In virtual environments like the metaverse, inclusivity is promoted through the creation of accessible and diverse spaces, enabling broad participation and overcoming barriers for individuals with disabilities or from diverse socio-economic backgrounds (Arpaci et al., 2022; Kar and Varsha, 2023). This argument is corroborated by the qualitative finding: "*Virtualization will revolutionize the retail industry. Just think from the perspective of an individual who has a disability or mobility issue; it can be a daunting task for them to go to physical stores to try out either a dress or check out interiors. With this, we can actually make them feel more comfortable by assessing products from their homes yet make them feel inclusive" (R11)*. Based on the above discussion, we hypothesize that:

H5. : Pro-environmental practices enhance the sustainable performance of the firm by positively influencing a) economic, b) environmental, and c) social performance outcomes.

3.1.4.3. The moderating role of technology infrastructure. The literature emphasizes the strategic importance of technology infrastructure in facilitating the effective adoption and implementation of emerging technologies within organizations (Enholm et al., 2022). For instance, Alsheibani et al. (2020) emphasize that suitable technological infrastructure is essential for organizations seeking to integrate AI effectively. This viewpoint is further reinforced by Wamba-Taguimdje et al. (2020), who stress the necessity for high-speed and infinitely scalable infrastructure to accommodate disruptive technologies' substantial computational demands.

Several studies have emphasized the multifaceted role of technology infrastructure, not only as a direct enhancer of organizational performance but also as a key determinant influencing various organizational processes and capabilities, especially in technology adoption and DCs development. Tallon and Pinsonneault (2011) investigated how flexible IT infrastructure enhances strategic alignment, empowering organizations to respond more effectively to strategic initiatives. Zhu and Kraemer (2005) examined how robust IT infrastructure moderates the success of e-commerce implementations, facilitating the adoption and effectiveness of online business models. Investigation by Gangwar et al. (2015) into the influence of existing information technology infrastructure on cloud computing adoption and benefits revealed that an organization's IT infrastructure readiness and compatibility with cloud services moderate the extent to which cloud computing can be effectively adopted and utilized to achieve strategic objectives.

Qualitative insights highlight that the metaverse, with its immersive virtual environments, requires infrastructure capable of facilitating real-time interactions, high-bandwidth data transfers, low-latency communications, and supporting large-scale user concurrency. The absence of such advanced infrastructure poses significant challenges to metaverse adoption by businesses, underscoring the crucial role of a robust technological foundation in leveraging the metaverse's benefits for businesses (Kumar et al., 2023). The experts emphasize the vital role of a robust technology infrastructure in enabling essential functionalities like high-quality video conferencing and real-time updates in virtual environments. Additionally, they stress the importance of infrastructure capable of supporting complex data analytics, AI, and seamless integration of digital tools for businesses to fully optimize their processes within the metaverse (Koohang et al., 2023). They claim that the efficacy of the metaverse in empowering stakeholders depends on accessible and high-quality technology infrastructure, which guarantees immersive experiences and promotes inclusion and involvement among varied stakeholders. They warn that unsustainable approaches in the development and management of technology infrastructure may intensify environmental problems, hindering the achievement of the metaverse's environmental advantages. Therefore, the establishment of sustainable infrastructure that integrates green technologies is essential for leveraging the metaverse's capacity to promote environmentally beneficial projects. These points of view are corroborated by the qualitative findings where one of the respondents states: "*See, the core benefit or advantage of the metaverse can be realized only if the technology infrastructure is robust and is accessible to all the stakeholders and participants. Technology infrastructure acts as the foundation upon which the metaverse is built and accessed, and without this, the potential of the metaverse to empower stakeholders would be limited significantly. Good infrastructure ensures a wider range of stakeholders can participate in the metaverse, from individuals in remote areas to small businesses looking to expand their digital presence …." (R11*). Based on the above discussion, we hypothesize that:

H6. : Technology infrastructure positively moderates the positive relationship between metaverse adoption and a) collaboration, b) business process optimization, c) stakeholder empowerment, and d) pro-environmental practices.

3.2. Study 2: Quantitative research method

3.2.1. Data collection and sample profile

Drawing from initial qualitative insights, this study presents a conceptual framework to assess the metaverse's influence on sustainable performance metrics. Subsequent quantitative investigation builds upon qualitative findings, shaping a research model grounded in the DCV framework (see Fig. 1). To operationalize this framework, a survey questionnaire was developed, integrating established metrics and subjected to online pretesting. Feedback from 10 industry experts and 6 academic scholars informed refinements to ensure clarity and coherence, enhancing the instrument's reliability for subsequent data collection.

Given the acknowledged challenges of implementing purely random sampling within the retail sector, as suggested in the extant literature (e.g., Srivastava and Kaul, 2014), this study has employed a hybrid approach of convenience and random sampling methods (Dash and Paul, 2021). This strategy is informed by scholarly recommendations that posit that convenience sampling can enhance participant response rates and support the execution of complex research designs particularly those focused on exploratory analysis (Cabeza-Ramírez et al., 2022). Before initiating the quantitative data collection, an a priori analysis was conducted to determine the necessary sample size to achieve an 80 % power, crucial for reliably detecting significant relationships in the hypotheses. Considering an effect size of 0.3, a significance level of 0.05, and encompassing 56 observed and 8 latent variables, the calculation indicated that a sample size greater than 236 would be appropriate for analysis. Subsequently, the main survey was administered, with 141 invitations sent online. Initially adopting convenience sampling, participants were approached via LinkedIn, Twitter, author networks, and the network of industry experts from Study 1, consistent with similar studies (e.g., Cabeza-Ramírez et al., 2022). A total of 71 completed and usable responses were received from the phase of convenience sampling. Subsequently, to address the inherent biases of convenience sampling, particularly to mitigate the possible effects of unbalanced covariates through non-random selection, augment the sample size, and introduce randomness to the sampling strategy (Cabeza-Ramírez et al., 2022; Etikan et al., 2016), a directory of the top 500 firms in the Indian retail industry was utilized, randomly selecting 350 firms whose managers were contacted and provided with study details ensuring data confidentiality. A total of 243 usable responses were collected from the random sampling phase of data collection. A total of 314 responses were collected between January and March 2024 by employing both convenience and random sampling, which surpassed the required minimum sample size for reliable model estimation. The demographic summary of participants is available in Appendix 6.

3.2.2. Measures

The measures employed in the study were derived from pre-existing scales and formulated upon a foundation of extant scholarly literature to assess the constructs. Metaverse adoption is measured using an eleven-item scale adopted from Orji et al. (2020) on a 7-point Likert scale ranging from 1 = “Strongly disagree” to 7 = “Strongly agree.” Economic performance, environmental performance, and social performance are measured using a six-item scale, each adopted from Paulraj (2011), Geng et al. (2017), and Katiyar et al. (2018) on a 5-point Likert scale ranging from 1 = “Strongly disagree” to 5 = “Strongly agree.” Technology infrastructure is measured using a four-item scale adopted from Limbu et al. (2014) on a 5-point Likert scale ranging from 1 = “Strongly disagree” to 5 = “Strongly agree.” Collaboration is measured using a five-item scale adopted from Cai et al. (2016), Dubey et al. (2020), and Zacharia et al. (2011) on a 5-point Likert scale ranging from 1 = “Strongly disagree” to 5 = “Strongly agree.” Business process optimization is measured using a seven-item scale adopted from Grover et al. (1998) and Lok et al. (2005) on a 7-point Likert scale ranging from 1 = “Strongly disagree” to 7 = “Strongly agree.” Pro-environmental practices is measured using a six-item scale adopted from Bissing-Olson et al. (2013) on a 5-point Likert scale. Stakeholder empowerment is measured using a six-item scale adopted from Shafieisabet and Haratifard (2020) on a 7-point Likert scale ranging from 1 = “Strongly disagree” to 7 = “Strongly agree.”

3.2.3. Assessing common method bias and non-response bias

While we used a self-administered survey for quantitative data collection in this study, common method bias (CMB) is a concern. To address this, a number of procedural remedies recommended by Podsakoff et al. (2003) were adopted. First, the survey design drew upon established literature and included positively and negatively structured statements to ensure that research model constructs were accurately captured. Second, a preliminary assessment was performed to ensure the clarity of the items, eliminate ambiguities, and confirm the understandability of the items. Third, we used different scale points, including both five and seven-point Likert scales, across the questionnaire to ensure a broader assessment of participants’ attitudes and perceptions, limiting the potential for pattern responses and anchoring (Podsakoff et al., 2003). Lastly, to control acquiescence and socially desirable answers, respondents were promised anonymity and encouraged to answer truthfully without the concern of negative judgments.

To address the possible CMB concerns, statistical methods were used, in addition to procedural mechanisms. Harman’s single-factor test, widely employed to discern CMB, was first applied and showed that the first factor explained only 29.16 % of the total variance, which falls well below the 50 % threshold value. Acknowledging Harman’s single-factor test limitations, the present study also implemented the marker variable approach, where a marker variable was included, selecting “fashion consciousness” as the marker variable due to its theoretical non-relevance to the study’s main variables and negligible correlation with them. This procedure did not change the statistical significance of the primary variables. Following the guidelines set forth by Hair et al. (2019), variance inflation factors (VIF) were also assessed, applying Kock (2015) to evaluate the collinearity. The analysis reveals that the average VIF was 1.399 for block VIF and 2.63 for full collinearity VIF, thus confirming that none of the values exceeded the accepted VIF value of 5. While these metrics cannot definitively rule out CMB, they suggest that its impact on the research outcomes is unlikely to be significant.

This study further employed two approaches to address non-response bias which is defined as differences between the characteristics or responses of non-participants compared to participants (Rogelberg and Stanton, 2007). First, a comparative analysis of responses collected immediately after dissemination and those gathered post-reminder was conducted. Responses collected immediately were termed early responses, while those received post-reminders were labeled late responses. The results of the *t*-test analysis indicated no statistically significant differences between the two studied groups. Second, in line with Wagner and Kemmerling’s (2010) recommendation, the present study used a double-sample strategy to alleviate potential non-response bias. We first re-contacted nonparticipants who never completed the survey and asked them to answer a brief survey by email. This stage generated 41 further responses. *t*-tests were subsequently performed comparing primary survey responses to those that completed the shorter version in order to determine if there were statistically significant differences in responses, and no significant differences in reported responses were found, suggesting that responses were similar across groups. Although systematic non-response bias cannot be entirely dismissed, the methods employed significantly limit the possibility of endangering the conclusions of this study.

3.2.4. Assessing endogeneity

Endogeneity is a crucial issue faced in the analysis of non-experimental data because it may cause the coefficients being estimated to be biased, inconsistent, and non-interpretable (Hult et al., 2018). This may occur if an independent variable is correlated with the error term, often as a result of problems with measurement, simultaneity, or omitted variables (Hill et al., 2021). To control for the first two sources of endogeneity, which are omitted variables and simultaneity, it is necessary to include the proper control variables in the model (Hill et al., 2021). We have accordingly controlled for these variables including organizational size (number of employees), organizational age, and industry segment, as these variables might significantly affect a firm’s sustainable performance. The third cause of endogeneity, which is measurement error can be detected through scrutiny of reliability and validity measures as part of measurement model evaluation.

The previous approaches can address the concerns of endogeneity, but it can never be absolutely ruled out. In order to further mitigate this concern, we employed a more advanced and precise approach to detect indications of endogeneity, i.e., the Gaussian Copula (GC) following the recommendation of Park and Gupta (2012). The GC approach directly models the correlation between endogenous regressors and the error term; such correlation would produce a statistically significant correlation, which is also an indication of endogeneity. Nonetheless, if the correlation shows significance, we can conclude that endogeneity may have an effect on the research model. Findings from our GC analysis suggest that potential endogeneity concerns do not have a significant impact on the results of the study given that all of the correlations were not statistically significant. Hence, our results indicate that there are no serious endogeneity issues in our study.

3.2.5. Data analysis

The primary method used to test the research model statistically was Partial Least Squares Structural Equation Modeling (PLS-SEM). This selection is due to various factors that emphasize the suitability of PLS-SEM for our study, unlike other SEM techniques like covariance-based SEM. Firstly, PLS-SEM is especially helpful for exploratory research aimed at extending current theoretical models, as it does not require an assumption of multivariate normality (Hair Jr et al., 2017). This flexibility is particularly appropriate to our study, which explores new or emerging phenomena or constructs not yet fully defined. The second most important rationale for using PLS-SEM is its predictive orientation. This approach emphasizes explaining the variance in dependent variables to improve the predictive capability of the model. Third, PLS-SEM is acknowledged for its competence in managing complex research models that involve detailed hypothesis interconnections (Dash and Paul, 2021). The primary advantage of PLS-SEM is its capacity to track and analyze relations and causal links in complex contexts and provides insights that are often hard to achieve by other methods (Hair et al., 2019). Furthermore, the method's efficiency with small sample sizes makes PLS-SEM particularly fitting for our study. Moreover, due to the moderate sample size and the various complex relationships we intend to investigate, the PLS-SEM approach allows for efficient estimation of path coefficients, thus enhancing our ability to conduct meaningful analysis. Considering the moderate size of our sample and the complex relationships we aim to explore, PLS-SEM provides a strong framework for estimating path coefficients efficiently, thereby enhancing our analytical capability. Thus, our selection of PLS-SEM is driven by its versatility, emphasis on prediction, flexibility in dealing with both reflective and formative constructs, and effectiveness in exploratory studies involving complex models. However, recognizing the complementary features of various methodologies, consistent with the view of Hair Jr et al. (2017) we aim to leverage the strengths of both PLS-SEM and covariance-based methods. In alignment with this guidance, we do use a covariance-based methodology to establish the psychometric properties of our measures, as well as using PLS-SEM to analyze the structural model, thereby allowing us to build on the inherent advantages of each method, ensuring a comprehensive and rigorous examination of our research questions.

3.2.6. Results

For the analysis of the research model, SmartPLS version 4 software was used in this study. The current analysis was conducted in accordance with the two-stage process consistent with the guidelines set forth by Hair et al. (2019). The measurement model was evaluated in the first stage, followed by the analysis of the structural model.

3.2.6.1. Measurement model. The assessment of the measurement quality for the proposed model included convergent validity, discriminant validity, and construct reliability assessment. The reliability of the model was assessed using Cronbach's alpha which was greater than the threshold value of 0.7. However, as Cronbach's alpha can frequently undervalue the internal consistency reliability of latent variables in PLS-SEM models, composite reliability was found to be a more suitable measure (Henseler et al., 2015). As shown in Appendix 7, the construct reliability for each construct was confirmed with composite reliability values above the acceptable level of 0.7. Convergent validity was determined using the Average Variance Extracted (AVE) measure, adhering to the criteria set by Fornell and Larcker (1981). An AVE value above 0.50 denotes adequate convergent validity, indicating that a latent variable, on average, explains more than half of the variance of its indicators (Hair et al., 2019). This criterion was satisfied by all constructs, with AVE values exceeding the 0.5 threshold, affirming their convergent validity as presented in Appendix 7, which also presents descriptive statistics and a correlation table. Discriminant validity was examined using the heterotrait-monotrait (HTMT) ratios and the Fornell & Larcker criterion. HTMT ratios below 0.85 suggested sufficient conceptual distinction among constructs (Henseler et al., 2015). Furthermore, the Fornell & Larcker criterion was employed, establishing discriminant validity when the square root of AVE values for each construct surpassed its correlations with other constructs, as shown in Appendix 8 and 9. The analysis indicates that the model has satisfactory reliability, convergent validity, and discriminant validity.

3.2.6.2. Structural model. The structural model was examined using the percentile approach with bootstrapping 5000 subsamples. Subsequent analyses involved reviewing the R^2 values associated with the endogenous constructs, which helped evaluate the structural model's explanatory capabilities, as shown in Appendix 9. Additionally, the model's predictive accuracy was examined using PLSPredict, with Stone-Geisser's Q^2 values serving as the metric for this assessment (Hair Jr et al., 2017). The obtained Q^2 values were notably above zero, underscoring the structural model's predictive validity (See Appendix 10). This evidence strongly supports the predictive validity of our model. In addition, the SRMR was utilized as a measure to evaluate the fit of the structural model. An SRMR value of 0.057, falling beneath the commonly accepted threshold value of 0.08, denoted a satisfactory fit of the model (Henseler et al., 2015).

Following the establishment of satisfactory explanatory power, predictive relevance, and good model fit, the evaluation of the path coefficients for the hypothesized relationships was conducted. The results of this analysis are detailed in Table 2 and presented in Fig. 2. H1 predicted that metaverse adoption would positively influence a) collaboration, b) business process optimization, c) stakeholder empowerment, and d) pro-environmental practices. The coefficient of metaverse adoption on collaboration, business process optimization, stakeholder empowerment, and pro-environmental practices and efficiency was positive and significant ($\beta = 0.469$, $p < .05$; $\beta = 0.684$, $p < .05$; $\beta = 0.384$, $p < .05$ and $\beta = 0.295$, $p < .05$ *respectively*), supporting H1a, H1b, H1c, and H1d.

H2 predicted that enhanced higher-order dynamic capability of collaboration would positively influence the economic, environmental, and social sustainability of the firms. The coefficient of collaboration on environmental and social sustainability are positive and significant ($\beta = 0.303$, $p < .05$; $\beta = 0.244$, $p < .05$, *respectively*), while the coefficient of collaboration on economic sustainability is insignificant ($\beta = 0.006$, $p > .10$). Thus, we find support for H2b, and H2c while failing to find support for H2a.

H3 predicted that enhanced higher-order dynamic capability of business optimization would positively influence the economic, environmental, and social sustainability of the firms. The coefficient of business optimization economic sustainability is positive and significant ($\beta = 0.132$, $p < .05$). Interestingly, the results indicate that the influence of business optimization on environmental and social sustainability are counterintuitive ($\beta = -0.103$, $p > .10$; $\beta = -0.107$, $p > .10$, *respectively*). Thus, we find support for H3a while failing to find support for H3b and H3c.

H4 predicted that enhanced higher-order dynamic capability of stakeholder empowerment would positively influence the economic, environmental, and social sustainability of the firms. The coefficient of stakeholder empowerment on economic, environmental and social sustainability are positive and significant ($\beta = 0.189$, $p < .05$; $\beta = 0.127$, p

Table 2
Hypothesis testing results.

Hypothesis	β coefficient	SE	T-value	p-value	Result
Direct Effects					
META - > COL (H1a)	0.469	0.058	8.035	0.000	Supported
META - > BO (H1b)	0.684	0.036	18.897	0.000	Supported
META - > EMP (H1c)	0.384	0.051	7.463	0.000	Supported
META - > PRO (H1d)	0.295	0.059	5.027	0.000	Supported
COL - > ECO (H2a)	0.006	0.073	0.052	0.478	Not Supported
COL- > ENV (H2b)	0.303	0.072	4.227	0.000	Supported
COL - > SOC (H2c)	0.244	0.074	3.376	0.000	Supported
BO - > ECO (H3a)	0.132	0.079	1.656	0.049	Supported
BO - > ENV (H3b)	−0.103	0.072	1.383	0.083	Not Supported
BO - > SOC (H3c)	−0.107	0.080	1.343	0.090	Not Supported
EMP - > ECO (H4a)	0.189	0.062	2.492	0.006	Supported
EMP - > ENV (H4b)	0.127	0.062	2.050	0.020	Supported
EMP - > SOC (H4c)	0.358	0.067	5.412	0.000	Supported
PRO - > EOC (H5a)	0.118	0.056	2.090	0.099	Supported
PRO - > ENV (H5b)	0.376	0.066	6.084	0.018	Supported
PRO - > SOC (H5c)	0.056	0.063	0.839	0.201	Not Supported
META - > ECO	0.129	0.071	1.817	0.038	Supported
META - > ENV	−0.086	0.080	1.082	0.142	Not Supported
META - > SOC	−0.051	0.070	0.731	0.250	Not Supported
Indirect Effects					
META - > EMP - > ECO	0.050	0.022	2.162	0.012	Supported
META - > EMP - > ENV	0.032	0.017	1.855	0.032	Supported
META - > EMP - > SOC	0.091	0.026	3.474	0.000	Supported
META - > BO - > ECO	0.081	0.046	1.734	0.039	Supported
META - > BO - > SOC	0.059	0.047	1.320	0.103	Not Supported
META - > BO - > ENV	0.074	0.045	1.647	0.087	Supported
META - > PRO - > ECO	0.022	0.014	1.728	0.042	Supported
META - > PRO - > ENV	0.079	0.025	3.247	0.001	Supported
META - > PRO - > SOC	0.012	0.014	0.795	0.200	Not Supported
META - > COL - > ECO	−0.002	0.033	0.051	0.478	Not Supported
META - > COL - > ENV	0.134	0.034	3.943	0.000	Supported
META - > COL - > SOC	0.109	0.035	3.092	0.001	Supported
Moderating Effect					
TI_ x META - > COL (H6a)	0.136	0.061	2.225	0.013	Supported
TI_ x META - > BO (H6b)	0.046	0.041	1.165	0.130	Not Supported
TI_ x META - > EMP (H6c)	0.075	0.046	1.647	0.091	Supported
TI_ x META - > PRO (H6d)	0.133	0.069	1.935	0.034	Supported

Note*- META represents metaverse adoption; COL represents collaboration; BO represents business process optimization; EMP represents stakeholder empowerment; PRO represents pro-environmental practices; ECO represents economic sustainability; ENV represents environmental sustainability; SOC represents social sustainability; and TI represents technology infrastructure.*

$< .05$; $\beta = 0.358$, $p < .05$, respectively). Thus, we find support for H4a, H4b and H4c.

H5 predicted that enhanced higher-order dynamic capability of pro-environmental practices would positively influence the economic, environmental, and social sustainability of the firms. The coefficient of pro-environmental practices on economic and environmental are positive and significant (*$\beta = 0.118$, $p < .10$; $\beta = 0.376$, $p < .05$, respectively),* while the coefficient of pro-environmental practices on social sustainability is insignificant (*$\beta = 0.056$, $p > .10$).* Thus, we find support for H5a, and H5b, while failing to find support for H5c.

To further assess the relationships between the metaverse and sustainability outcomes in terms of economic, environmental, and social sustainability, we followed the framework developed by Zhao et al. (2010) to determine the mediating effects. Initially, the analysis focused on assessing the significance of the indirect effects through the mediator variable. In instances where the indirect effects were deemed nonsignificant for particular constructs, it was inferred that mediation did not play a role within the examined relationship. Conversely, upon identifying significant indirect effects, the investigation proceeded to evaluate the direct effects. If the direct effect of metaverse on economic, environmental, and social sustainability were significant in the presence of the mediator, then the mediating effect would be partial; however, if the direct effect is insignificant in the presence of the mediators, then there would be the presence of full mediation. The result of the mediation analysis suggests that the indirect effect of metaverse on economic, environmental, and social sustainability was significant (*$\beta = 0.155$, $p < .05$; $\beta = 0.185$, $p < .05$; and $\beta = 0.152$, $p < .05$ respectively).* Further, the indirect effect of the metaverse on economic, environmental, and social sustainability through stakeholder empowerment was significant (*$\beta = 0.05$, $p < .05$; $\beta = 0.032$, $p < .05$; and $\beta = 0.091$, $p < .05$ respectively).* The findings from our analysis indicate that metaverse enhances firms' ability to empower stakeholders, which in turn positively affects economic, environmental, and social sustainability. Further, the result from mediation analysis reveals that the metaverse's indirect effect on economic and environmental sustainability through business process optimization was significant (*$\beta = 0.081$, $p < .05$; and $\beta = -0.060$, $p < .10$, respectively*). However, the indirect effect of metaverse on social sustainability through business process optimization is insignificant. Further, the metaverse's indirect effect on economic and environmental sustainability through pro-environmental practices was significant (*$\beta = 0.022$, $p < .05$; and $\beta = 0.079$, $p < .05$, respectively*). However, the indirect effect of metaverse on social sustainability through pro-environmental practices is insignificant. Finally, the metaverse's indirect effect on the environment and social sustainability through collaboration was significant (*$\beta = 0.134$, $p < .05$; and $\beta = 0.109$, $p < .05$, respectively).* However, the indirect effect of metaverse on economic sustainability through pro-environmental practices is insignificant. Since the direct effect of metaverse on economic sustainability was found to be significant (*$\beta = 0.128$, $p < .05$*), partial mediation was concluded for economic sustainability. However, since the direct effect of metaverse on environment and social sustainability was insignificant (*$\beta = 0.085$, $p > .10$; and $\beta = 0.046$, $p > .10$, respectively),* full mediation was concluded.

Next, we investigated the moderating effect of technology infrastructure as proposed in H6. The coefficient of technology infrastructure on the association between metaverse adoption and collaboration, stakeholder empowerment, and pro-environmental practices was positive and significant (*$\beta = 0.136$, $p < .05$; $\beta = 0.075$, $p < .10$; and $\beta = 0.133$, $p < .05$ respectively*), while the moderating impact of technology infrastructure in the relationship between metaverse adoption and business process optimization is insignificant (*$\beta = 0.046$, $p > .10$).* Consequently, the findings support H6a, H6c, and H6d, while failing to find support for H6b.

3.2.6.3. Robustness check. The assessment of model fit is performed through the application of the $\chi 2$ statistic in conjunction with absolute and incremental fit indices. Absolute fit indices evaluate the extent to which a proposed model succeeds in mirroring the data observed within a specific sample (Shah and Goldstein, 2006). Conversely, incremental fit indices are tasked with assessing the improvement in fit that a proposed model offers over a baseline reference model (Shah and Goldstein,

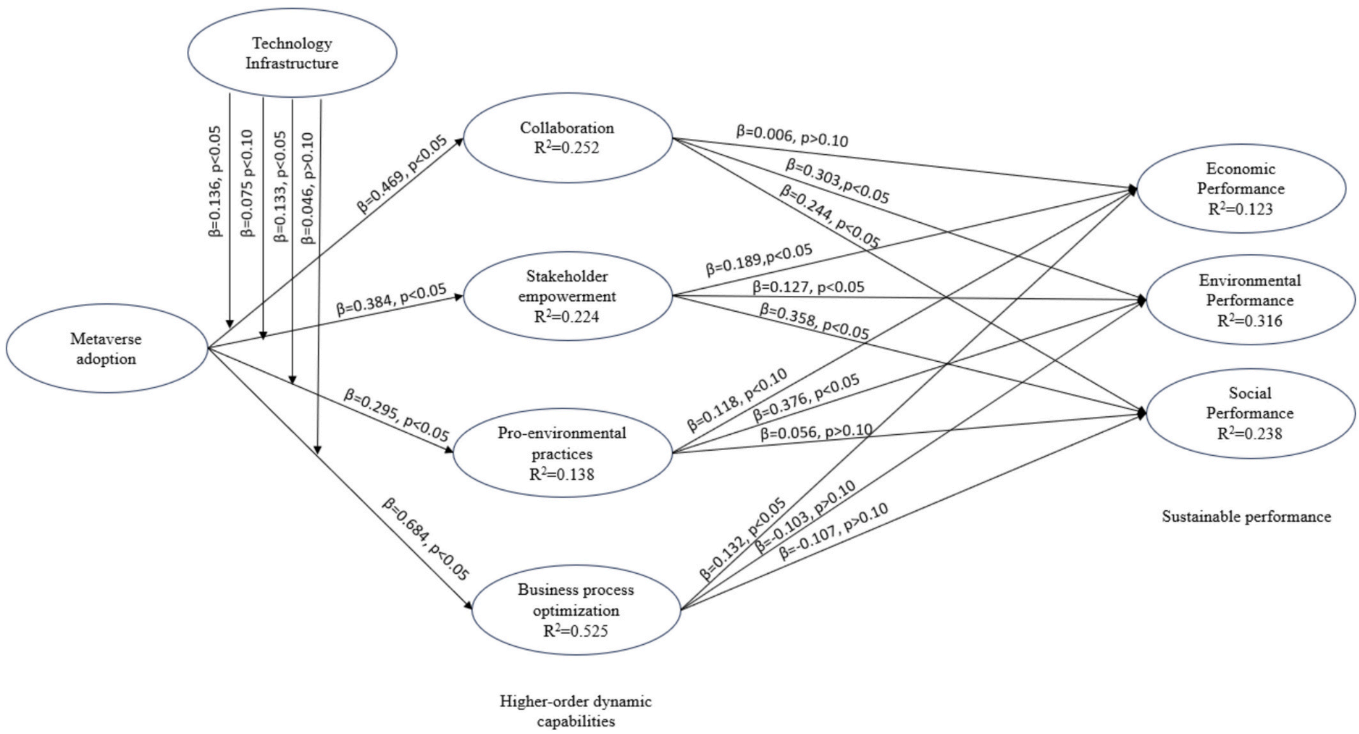

Fig. 2. Estimated structural model.

2006). Among the pivotal measures routinely harnessed to determine model adequacy are the Root Mean Square Error of Approximation (RMSEA), the Goodness-of-Fit Index (GFI), the Comparative Fit Index (CFI), and the Standardized Root Mean Square Residual (SRMR). An initial confirmatory factor analysis (CFA) conducted with AMOS 24, demonstrated satisfactory psychometric properties. This was evidenced by all standardized regression weights attaining statistical significance at the $p < .001$ level, with the ratio of $\chi 2/\mathrm{df}$ at 1.450, and the indices: GFI at 0.818, CFI at 0.948, Tucker-Lewis Index (TLI) at 0.943, RMSEA at 0.038, and SRMR at 0.056, underscoring the robustness of the model fit. Particularly, the GFI index surpassed the widely accepted benchmark of 0.80 (Sharma et al., 2005), albeit the remaining fit statistics presented a more favorable perspective, thereby corroborating the attainment of an acceptable model fit. Collectively, these findings underscored the conclusion that the measurement model exhibited a sound fit to the empirical data.

To evaluate the robustness of the findings related to the proposed model, this investigation adopted a robustness test procedure that aligns with methodologies prevalent in contemporary research. Initially, adhering to the recommendations by Kotsi et al. (2018), this study integrated three sub-dimensions of sustainable performance into a composite second-order dimension within an alternate model. Subsequently, this procedure was replicated to assess the fit and the impact pathways of the alternative model. Furthermore, an analysis comparing the original hypothetical model against the alternative model was conducted, examining direct, mediating, and moderating effects. The alternative model demonstrated an inferior fit in comparison to the originally proposed model, as indicated by the following metrics: $\chi 2/\mathrm{df}$ at 1.875, and the indices: GFI at 0.769, CFI at 0.896, TLI at 0.889, RMSEA at 0.053, and SRMR at 0.061. In alignment with the hypothesis, metaverse adoption was found to exert a direct, positive influence on the DCs of collaboration, business optimization, stakeholder empowerment, and pro-environment practices. Moreover, the moderating effect of technology infrastructure yielded significant outcomes for hypotheses H6a, H6c, and H5d. Consequently, the alternative model confirmed the consistency and robustness of the hypothesis results.

4. Discussion of results

Employing a sequential mixed-method approach, the study investigated how metaverse adoption influences economic, environmental, and social sustainability in the retail sector. Grounded in the DCV framework, qualitative data analysis (Study 1) generated five propositions addressing literature gaps. These propositions were empirically tested in a subsequent quantitative study (Study 2) to validate outcomes from the qualitative analysis.

Our study contributes to the ongoing discussion on the metaverse's sustainability implications by addressing a key gap in existing research (Abumalloh et al., 2023). While digital technologies are often framed as tools to boost efficiency, our findings suggest that the metaverse has the potential to fundamentally transform how organizations engage with stakeholders and implement sustainability practices (Buhalis et al., 2023). Despite concerns regarding challenges and risks, our research demonstrates that the distinct attributes of the metaverse allow businesses to cultivate DCs. These capabilities include fostering collaboration, business optimization, empowering stakeholders, and pro-environmental practices. Rather than being limited to operational enhancements, these findings resonate with contemporary debates on digital transformation (Barrera and Shah, 2023; Dwivedi et al., 2022; Koohang et al., 2023; Richter and Richter, 2023; Yoo et al., 2023). The metaverse might also contribute to environmental problems by reinforcing elements of digital consumerism that mirror the unsustainable consumption patterns present in the physical world (Hadi et al., 2024). While these commodities and services are virtual, they rely on tangible resources, creating energy and resource consumption. Furthermore, the interactive aspect of the metaverse may encourage physical consumption by virtually signaling products or lifestyles and affecting real-world consumption patterns (Kim et al., 2023; Yoo et al., 2023). On the social sustainability side, the metaverse may highlight a host of inequities and ethical dilemmas. The need for advanced infrastructure intrinsic to the technology deepens the digital divide and excludes low-income persons and communities (Aysan et al., 2024). Additionally, changes in the workplace and labor markets resulting from the integration of the metaverse are having disruptive effects, leading to the creation of new job opportunities as well as threatening traditional roles. Consequently, our study examines the research question: *RQ1: What impact does the metaverse have on economic, environmental, and social sustainability?*

Although existing studies (e.g. Abumalloh et al., 2023; Al-Emran, 2023; Arpaci et al., 2022; Eggenschwiler et al., 2024; Rajguru and Brüggemann, 2024) delve into the possible transformative role of a metaverse in enhancing sustainability outcomes), however to the best of our knowledge, there is limited exploration of the precise mechanism by which metaverse impacts sustainable performance outcomes. Existing studies, like those by Buhalis et al. (2023) and Koohang et al. (2023), tend to be conceptual in nature or focus primarily on operational advantages. Our results, in contrast to prior studies, demonstrate the important function that DCs play as a crucial channel that improves durable performance outcomes. In particular, our results offer strong proof that, within the framework of our investigation, the inherent characteristics of the environment support the development of DCs (collaboration, business process optimization, stakeholder empowerment, and pro-environmental practices). However, an interesting finding of our study is the counter-intuitive role of business process optimization on environmental and social sustainability, the insignificant effect of collaboration on economic sustainability, and pro-environmental practices on social sustainability. This sheds light on the fine line organizations have to walk in using digital technologies towards sustainability goals. The unexpected results can be explained by the paradoxical dynamics of digital over-saturation and sustainability trade-offs (Chen et al., 2023; Yoo et al., 2023). Shifting to digital tools such as the metaverse may cause a misalignment for organizations that, in seeking efficiency metrics, may inadvertently bolster operational economies at the expense of finely tuned sustainability approaches (Hadi et al., 2024; Kumar and Shankar, 2024; Pamucar et al., 2022). Business process optimization typically drives the greatest operational optimizations without encompassing sustainable resource consumption; efficiencies achieved through individual actions may inadvertently exacerbate environmental degradation by prioritizing costs and speed above overarching sustainability goals this may help to explain the findings. The fact that implementation of optimization technologies requires substantial infrastructure and energy potential, which would likely negate the environmental benefits (Abumalloh et al., 2023). Socially, these technologies could lead to a decrease in meaningful human interaction, especially in collaborative environments, which will impair inclusive organizational cultures needed for social sustainability (Arpaci et al., 2022). The insignificant effects of collaboration on economic sustainability could be explained by the infrastructure of the metaverse, which is relatively decentralized, and since it emphasizes inclusiveness and flexibility, it may weaken accountability and decisional efficiency (Goldberg and Schär, 2023). While working together with other stakeholders, often in fragmented ecosystems, each stakeholder may aim for localized goals and priorities rather than collective economic outcomes (Yoo et al., 2023). Such lack of alignment inhibits the rise of shared strategies needed to create sustained economic value (Eggenschwiler et al., 2024; Gillani et al., 2024), especially in retail, which is traversing the path of digital transformation. The limited influence of pro-environmental practices on social sustainability may be related to their digital focus. Although these practices largely center on diminishing virtual waste, or improving resource efficiency within immersive spaces, they often overlook concrete social implications (Kshetri and Dwivedi, 2023). Metaverse-catered virtual goods and decentralized systems promote environmental goodness but undoubtedly eliminate manual employment opportunities in the traditional supply chain (Aysan et al., 2024). The energy-intensive infrastructure necessary to enable metaverse actions, such as BCT and data facilities, might exacerbate inequities to the point of limiting access to areas that lack the availability of technological infrastructure (Rajguru and Brüggemann, 2024). This dissonance is also a case of how sustainable practices in the metaverse can ultimately be of higher environmental benefit, while also perpetuating social inequity, lack of inclusivity, and poor livelihoods for marginalized communities. Consequently, we address the second research question: *RQ2: What is the underlying mechanism through which the metaverse impacts economic, environmental, and social sustainability?*

While Dwivedi et al. (2022) and Alsheibani et al. (2020) view technology infrastructure as a foundational enabler, our study uniquely identifies its moderating effects on the association between metaverse adoption and collaboration, stakeholder empowerment, and pro-environmental practices. This emphasizes its foundational role in enabling immersive experiences and strategic objectives within the metaverse (Kumar et al., 2023). The importance of a robust technology infrastructure to facilitate DCs; which in the context of our study is collaboration, empower stakeholders, and promote pro-environment practices in the metaverse is evident from these results. Additionally, the analysis reveals that the moderating effect of technology infrastructure on business process optimization appears to be insignificant, which suggests that optimizing business processes leveraging the metaverse needs to go beyond the infrastructure of technology and requires more nuanced consideration (Kumar et al., 2023). In other words, although having a strong technological infrastructure basis is the foundation for immersive interaction in the metaverse, its factors on business process optimization can significantly vary based on strategic technology application, synergy between metaverse technologies and existing operations, as well as alignment with organizational strategies (Chen and Ruan, 2024). Consequently, we address the third research question: *RQ3: Does technology infrastructure moderate the relationship between metaverse adoption and dynamic capabilities?*

4.1. Theoretical contribution

Our study contributes significantly to sustainability theory by addressing the emerging context of the metaverse. While Al-Emran's (2023) study explores technology's impact on economic, environmental, and social sustainability, its discussion lacks clarity and rigor in explaining underlying mechanisms. Existing studies on the direct influence of the metaverse on sustainability outcomes often remain conceptual or narrowly focused, overlooking a comprehensive inquiry into how fundamental metaverse features affect sustainable performance (Abumalloh et al., 2023; Arpaci et al., 2022; Koohang et al., 2023). Our research addresses this gap by clarifying the influence of the metaverse on economic, environmental, and social sustainability via DCs. This research addresses the need for a comprehensive examination of the environmental and socioeconomic effects of the metaverse, as highlighted by Eggenschwiler et al. (2024) and Klaus and Manthiou (2024). Our findings reveal that features of the metaverse, such as persistence, immersion, and customization, have a positive influence on capabilities like collaboration, streamlining business processes, empowering stakeholders, and encouraging practices. These ultimately lead to improvements, in sustainability outcomes for companies. This paper challenges simplistic narratives by providing insights, based on evidence, into how the metaverse serves the dual purpose of promoting sustainability while requiring careful governance to mitigate any drawbacks. It fosters theoretical discussions on technology's role in sustainable development, advocating for an approach in future research endeavors.

Our study addresses a notable gap in the literature by integrating environmental and social dimensions of sustainability into the analysis of the metaverse, which has primarily focused on economic aspects (Deveci et al., 2022; Koohang et al., 2023; Pamucar et al., 2022, 2023). By encompassing all three sustainability dimensions, our research promotes a more holistic approach to studying technological phenomena like the metaverse, broadening research agendas. Our findings reveal that metaverse adoption positively influences economic, social, and environmental dimensions through dynamic capabilities. This contribution advances the ongoing debate regarding the metaverse's influence on environmental and social sustainability, which has ranged from optimistic predictions to cautious skepticism. While concerns exist about its environmental impact and exacerbating social inequalities, proponents argue for innovative solutions and inclusive virtual communities. Our study empirically demonstrates how leveraging dynamic capabilities can mitigate risks and enhance sustainability outcomes, addressing the dual nature of the metaverse's impact.

Moreover, our research advances the DCV framework by adapting it to the distinct context of the metaverse in the retail industry, addressing a deficiency in the current literature (Teece et al., 1997; Teece, 2007; Ghosh et al., 2022; Zabel et al., 2023). By broadening conventional interpretations of dynamic capacities to encompass digital and virtual contexts, we illustrate how the metaverse represents a novel frontier for strategic adaptation and competitive advantage (Buhalis et al., 2023). Furthermore, our research outlines the precise impacts of dynamic capacities on sustainability aspects inside the metaverse, offering a framework for strategic implementation for organizations to navigate and establish themselves effectively within the virtual ecosystem.

Our study contributes to the exploration of technology infrastructure as a boundary condition for effective metaverse adoption, enriching our understanding of contextual factors (Kumar et al., 2023). By analyzing how technology infrastructure affects the association between metaverse adoption and DCs we underscore the importance of having robust technology infrastructure for strategic adaptability (Kumar et al., 2023). By expanding the DCV framework to account for technical prerequisites, the research acknowledges the need to address infrastructural challenges. These findings lay the groundwork for further studies to investigate other contextual factors that may shape the role of dynamic capabilities in cutting-edge digital environments like the metaverse.

4.2. Practical contribution

Our study presents practical implications for leaders and decision-makers addressing digital transformation while promoting sustainability in the retail sector. The results highlight the transformative potential of the metaverse, not merely as a technological innovation, but as a strategic enabler of dynamic capabilities that further advance organizational sustainability goals. Our research offers an in-depth understanding of the relationship between the metaverse and economic, environmental, and social sustainability, helping managers create expectations and pragmatic assessments of the metaverse's impact moving forward. As such, retail managers should consider the adoption of the metaverse as a strategic lever for attaining sustainability goals. For example, using real-time tracking, immersive virtual interactions, and simulation tools, firms can detect inefficiencies, optimize resource use, and reduce waste.

As collaboration plays an important role in promoting environmental and social sustainability but does not directly lead to economic results, this finding shows that managers have to find ways to integrate profitability objectives into their collaboration strategies. To do this, retailers must craft metaverse-enabled partnerships that present value co-creation through new product designs and sustainable supply chain redesigns. Incentivizing partnerships among ambitious collaborators working collectively to reduce carbon footprints and improve supply chain transparency while supporting initiatives with wider sustainability objectives is important.

The counterintuitive conclusions regarding the limited impact of business process optimization on environmental and social outcomes need careful consideration. While business process optimization supports positive economic growth, managers must ensure that this growth is not achieved at the expense of broader sustainability objectives. This includes addressing unintended consequences such as increased energy demand, generation of electronic waste, and the exacerbation of digital inequity. This necessitates the incorporation of sustainability measures, including carbon footprint and community effect, into decision-making processes, and the utilization of methods such as Life Cycle Assessment (LCA) to assess long-term consequences. Managers implement reskilling programs to address job displacement caused by automation.

Stakeholder empowerment was identified as a key enabler for sustainability in all aspects. As such, managers must be driven to focus on metaverse-based platforms, democratizing access, upskilling staff, and fostering community and belonging. For example, platforms for immersive and virtual training can be leveraged to create a sustainability-oriented culture by enabling stakeholders to actively participate in environmental and social initiatives. This level of empowerment not only fosters stakeholder confidence but also bolsters the firm's capability to fulfill regulatory expectations and market demand for ethical business practices.

The significance of pro-environmental practices in economic and environmental sustainability highlights the necessity for companies to implement metaverse technologies for real-time resource monitoring and ecological impact evaluations. Managers must establish systems for meticulous monitoring of emissions, resource utilization, and waste management, ensuring alignment with global sustainability standards. The diminished effect of these practices on social outcomes underscores a deficiency that necessitates rectification by supplementary techniques, such as the advancement of equitable labor practices or the encouragement of community-focused initiatives. Finally, the moderator role of technological infrastructure indicates that robust infrastructure strengthens the influence of metaverse adoption on collaboration, stakeholder empowerment, and pro-environmental practices. However, the limited impact of technology infrastructure on business process optimization indicates that infrastructure alone cannot drive the needed investments. Managers must prioritize the integration of metaverse technologies with strategic planning and current workflows to fully realize their potential. This necessitates leadership alignment and interdepartmental coordination to guarantee that process enhancements yield durable and equitable results.

4.3. Limitation and future research scope

There are certain limitations that must be acknowledged when interpreting the results of our study. First, while emphasizing methodological rigor, we noted inconsistencies between the qualitative and quantitative findings, necessitating greater exploration in subsequent research to enhance our comprehension and broaden the study's impact. Secondly, as a cross-sectional survey, this study does not determine causal linkages, indicating the necessity for longitudinal studies or experimental designs in future research efforts. Finally, our study highlights the importance of technology infrastructure as a boundary condition in the connection between metaverse adoption and dynamic capabilities, there also exist other constructs, such as environmental dynamism, organizational culture, leadership, or regulatory requirements, that can offer contextual information to provide a comprehensive explanation of how firms draw on the metaverse to improve economic, environmental, and social sustainability. This would lead to more robust theoretical lenses that map dynamic capabilities against a broader range of moderating factors and would also contribute to the articulation of the prescriptive capacity of strategizing in the digital and virtual market realm.

CRediT authorship contribution statement

Thanos Papadopoulos: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Sirsha Pattanayak:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **M. Ramkumar:** Writing – review & editing, Writing – original draft, Validation, Methodology, Conceptualization.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techfore.2025.124189.

Data availability

Data will be made available on request.

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