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Sustainable business model innovation: A technology affordance perspective in the New Space Economy

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ABSTRACT

Despite the recent hype surrounding the transition from a publicly funded space industry to a commercially driven New Space Economy, the potential of space technology to address societal challenges remains largely underexplored. In response to recent calls to consider private firms as active contributors to addressing the grand challenges associated with the UN 2030 Sustainable Development Agenda, this study builds on previous research on sustainable business model innovation and adopts a technology affordance perspective to examine how firms can leverage space technology for sustainable innovation. Through a comparative multiple case study of 11 international entrepreneurial ventures in the New Space Economy, we identify three key space technology affordances that align the value mechanisms of their business models with their contributions to sustainability goals. Specifically, our findings illustrate how entrepreneurial ventures use space technology to overcome transaction obstacles in reaching and including previously excluded stakeholders, employing space technology as a *sharpshooter*, *Trojan horse*, or *piggy bank* in their pursuit of sustainable business model innovation. This study contributes to the literature on sustainable business models and the New Space Economy, offering valuable implications for management practice and policy.

1. Introduction

The increasing frequency of extreme climate events and growing social inequalities have highlighted the urgent need to refocus the global agenda on tangible actions for sustainable development (United Nations, 2015). In 2015, the United Nations introduced the 2030 Agenda for Sustainable Development, which outlined 17 sustainable development goals (SDGs) and called on organizations around the world to act as agents in addressing pressing societal challenges (Mio et al., 2020; Rosati et al., 2022). This initiative spurred a growing body of literature investigating how for-profit organizations can contribute to the sustainability goals through their business models (Bocken et al., 2014; Evans et al., 2017; Snihur and Bocken, 2022). Most management studies have focused on the internal integration challenges of incorporating new sustainability-related activities into firms' existing business models (Bocken and Geradts, 2020; Geissdoerfer et al., 2023; Olesson et al., 2023; Ringvold et al., 2023). However, there is a growing need to examine external barriers to contributing sustainability goals, particularly how organizations overcome obstacles that arise from a mismatch between their offerings and customer needs or expectations (Geissdoerfer et al., 2023; George et al., 2016; Norris, 2024; Sanasi et al., 2024). These include customers' inability to afford a firm's offering, difficulty in accessing its products and services, or unwillingness to pay due to a perceived lack of value (Santos et al., 2015).

Although challenging, a growing body of literature suggests that emerging technologies (Bailey et al., 2022; Grodal et al., 2015; Haessler et al., 2022) can help firms overcome external barriers to contributing to sustainability goals (Broccardo et al., 2023; Di Vaio et al., 2020; George et al., 2021), as mobile payment technologies did for low-income populations (Yunus et al., 2010; Rakshit et al., 2021). While earlier emerging technologies have moved beyond the experimental stage and demonstrated their positive societal impact (Islam, 2017), technological advances are uncovering additional opportunities for sustainable development (Rotolo et al., 2015). In particular, innovations in satellite miniaturization, launch vehicle reusability, and space-digital interoperability – supported by policy and regulatory decisions (e.g., the Commercial Orbit Transportation Program and the Commercial Launch Competitiveness Act) – have triggered a paradigmatic shift in the space

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industry. This shift, from the public-sector-driven, science-push focus of the traditional space industry to the private-sector, commercial-pull dynamics of modern space activities, is broadly referred to as the New Space Economy (Fuchs et al., 2024; Vittori et al., 2022; Weinzierl, 2018).

Building on these advances, space experts are increasingly calling for research into the potential applications of space technology to address societal challenges (Pelton et al., 2017). They emphasize the role of New Space Economy firms in exploiting these innovative technologies (Balogh et al., 2017; Heldt and Beske-Janssen, 2023). For example, in March 2023, researchers used a constellation of nine commercial satellites operated by GHGS to identify a methane leak in Gloucestershire, UK. Supported by the European Space Agency's mission to detect greenhouse gas emissions, the satellites tracked the leak (caused by a faulty pipeline) over time. The findings were reported to the pipeline owner, who promptly repaired the leak, avoiding potentially dangerous consequences for the local population (Dowd et al., 2023). This case illustrates how space technology is expanding its applications across diverse end-user industries, enabling innovative business models that address the needs of a wide range of stakeholders (Evans et al., 2017; Denis et al., 2020; Rottner et al., 2021; Paravano et al., 2023). Based on these considerations, we argue that technology – particularly space technology – offers significant opportunities for business model innovation aimed at advancing sustainability goals by mitigating external barriers to their broader contribution. Building on the growing recognition of technology (George et al., 2021) and business model innovation (Snihur and Bocken, 2022) as drivers of societal impact, this study adopts a technology affordance perspective (Bailey et al., 2022; Hutchby, 2001; Leonardi, 2011) to examine *how firms in the New Space Economy can leverage space technology affordances for sustainable business model innovation*, referring to business model innovation aimed at contributing to sustainability goals (Broccardo et al., 2023; Ringvold et al., 2023). The affordance perspective, defined as the "action possibilities and opportunities that emerge from actors engaging with a focal technology" (Faraj and Azad, 2012, p. 241), represents a key novelty of this study, complementing the dominant technocratic perspective in the literature on how firms can leverage emerging technologies to promote sustainable development (Palmié et al., 2024).

In particular, we conduct a comparative multiple case study (Eisenhardt, 1989, 1991) of 11 entrepreneurial ventures operating in the New Space Economy that address one or more of the SDGs. Using data from semi-structured interviews with venture executives, supplemented by archival records, public events, and additional sources, we develop an interpretive model to examine how entrepreneurial ventures leverage space technology affordances for sustainable business model innovation. Our findings reveal how these ventures harness the intrinsic features of space technology to identify actionable opportunities that help them overcome external obstacles to integrating societal impact into their business models, as highlighted by Santos et al. (2015).

Our study contributes to the ongoing discourse on sustainable business model innovation and the emerging literature on the New Space Economy in several ways. First, we address recent calls to expand scholarly understanding of business model innovation for sustainability (Snihur and Bocken, 2022) and its relationship to technology (George et al., 2021) through the lens of new-to-the-industry business model innovation (Foss and Saebi, 2018). Specifically, we adopt a technology affordance perspective (Bailey et al., 2022; Leonardi, 2011; Palmié et al., 2024) to unpack how the intrinsic features of space technology can help firms overcome transaction obstacles to sustainable business model innovation (Santos et al., 2015).

Second, we contribute to the discussion on the complexity of implementing sustainable business model innovation (Bocken and Geradts, 2020; Ringvold et al., 2023) by highlighting the importance of value mechanisms that go beyond sustainable value creation, namely sustainable value delivery and sustainable value capture (Norris, 2024). By identifying technology affordances and demonstrating how technology features enable firms to overcome external barriers (Palmié et al., 2024), we complement existing discussions by highlighting the role of entrepreneurial ventures and their novel business model innovations in addressing societal challenges. This perspective, which links entrepreneurial ventures to societal goals, has received limited attention in the literature (Seelos et al., 2023).

Third, we contribute to the emerging body of studies on the New Space Economy (e.g., Denis et al., 2020; Rottner et al., 2021; Vittori et al., 2022; Weinzierl, 2018) by providing an empirical account of how firms can leverage space technology to advance the SDGs. This empirical evidence revisits and extends previous conceptual studies that have highlighted the potential of space technology in this context (Balogh et al., 2017; Heldt and Beske-Janssen, 2023; Pelton et al., 2017). In addition, we contribute to the recent debate on how different stakeholders perceive the value of the New Space Economy (Paravano et al., 2023) by illustrating how the ability of space technology to mitigate transaction obstacles to sustainability can promote the broader adoption of New Space Economy applications, with significant societal implications.

Our study also offers valuable insights for managers and entrepreneurs. It provides a practical framework for linking the core features of space technology to the challenges firms face in implementing sustainable business model innovations, as well as actionable guidance for addressing the emerging space sustainability paradox (Wilson and Vasile, 2023).

2. Theoretical background

2.1. Sustainable business model innovation and the role of technology

Business model innovation refers to the search for new logics (Casadesus-Masanell and Zhu, 2013) through "designed, novel, non-trivial changes to the key elements of a firm's business model" (Foss and Saebi, 2017, p. 201). In other words, the value mechanisms that define how the firm creates value for a target set of customers (value creation), delivers that value (value delivery), and captures value from the market (value capture) (Teece, 2010). Business model innovation can manifest in two ways: (1) new-to-the-firm innovations that introduce changes to a firm's existing business model, and (2) new-to-the-industry innovations that transform an industry's established business model paradigm (Foss and Saebi, 2018).

For example, Netflix's launch of video streaming services was a new-to-the-industry business model innovation that disrupted century-old Hollywood practices for creating and distributing movies. Conversely, the launch of Disney+ was a new-to-the-firm business model innovation for the Walt Disney Company, which adopted the established video-streaming paradigm as part of its business model (Sanasi et al., 2022). According to prior studies, established firms typically focus on new-to-the-firm business model innovations, using their existing resources to reconfigure and strengthen their competitive position (Demil and Lecocq, 2010; Doz and Kosonen, 2010).

In contrast, entrepreneurial ventures often drive new-to-the-industry business model innovations that challenge the existing value creation, delivery, and capture paradigms (Amit and Zott, 2001; Chesbrough and Rosenbloom, 2002). Accordingly, the literature on business model innovation emphasizes that while established firms face internal challenges, such as entrenched practices and routines, entrepreneurial ventures challenge broader industry norms (Foss and Saebi, 2018).

In recent decades, growing concerns about sustainability have led scholars to explore how business model innovation can address social, environmental, and economic challenges (Elkington, 1997; Foss and Saebi, 2017). This has led to the emergence of sustainable business model innovation, a specific form of innovation designed to achieve environmental, social, and/or economic impact (Bocken and Geradts, 2020; Ringvold et al., 2023). For such business model innovation to be considered sustainable, its value mechanisms must be explicitly aligned with societal goals (Ringvold et al., 2023; Broccardo et al., 2023). The UN has further emphasized the role of business in advancing its Sustainable Development Agenda, recognizing it as a key player in addressing societal challenges (Di Vaio et al., 2020; Rosati et al., 2022).

This perspective places firms and their strategies at the center of efforts to contribute to sustainability goals. However, while sustainable business model innovation has received increasing attention in recent years (e.g., Baldassarre et al., 2017; Bocken and Geradts, 2020; Velter et al., 2020), the implementation of such innovations in individual firms remains highly challenging. Research consistently highlights significant internal and external barriers, ranging from resource constraints to stakeholder misalignment, which hinder sustainable business model innovation (Bocken et al., 2014; Evans et al., 2017).

Previous studies have focused extensively on identifying, classifying, and analyzing the barriers that firms face in implementing sustainable business model innovation, as well as the drivers and forces that can help overcome these challenges. For example, Madrid-Guijarro and Duréndez (2024) studied the adoption of sustainable business model innovation in small and medium enterprises (SMEs). Their findings emphasize that top management's commitment to sustainability plays a critical role in aligning business goals with environmental impacts throughout the organization. Similarly, Geissdoerfer et al. (2023) examined SMEs adopting circular business models, identifying 25 barriers (spanning legal, financial, technical, and organizational dimensions) and categorizing them based on the significance of the changes introduced by these new models.

Other studies have examined the barriers faced by large, established companies in pursuing sustainable business model innovation. For example, Bocken and Geradts (2020) categorize the barriers into institutional, strategic, and operational challenges, noting the need for firms to develop dynamic capabilities to address them. Broccardo et al. (2023) adopt a contingency perspective to distinguish between organizational and industry-level variables, demonstrating that the same organizational factors can act as either drivers or barriers depending on specific contingencies. Similarly, Olesson et al. (2023) examine how different institutional logics can act as either drivers or barriers depending on the business model component in question.

Despite this growing body of research, much of the literature focuses primarily on the internal barriers that different types of established firms face in implementing sustainable business model innovations and integrating sustainability into their existing business activities (e.g., Ringvold et al., 2023). However, internal barriers are not the only challenges to contributing to sustainability goals. Indeed, research suggests that sustainable entrepreneurs often perceive external barriers, such as institutional and market challenges, as even more threatening (Hoogendoorn et al., 2019). Moreover, some scholars argue that the literature on sustainable business model innovation lacks a clear connection between firms and their target stakeholders (Norris, 2024). For example, the value propositions designed by firms are often not aligned with customer needs or expected sustainability standards (Geissdoerfer et al., 2023).

This discrepancy highlights a significant research gap: external barriers to sustainable business model innovation, arising from factors outside the firm's boundaries, remain underexplored and a critical area for advancing scientific understanding. Santos et al. (2015) provide a foundational framework by identifying *three transaction obstacles* to introducing social impact into a social enterprise's business model: (i) inability to pay, reflecting the financial difficulties of target customers in affording the offering; (ii) difficulty of access, reflecting the challenges customers or beneficiaries face in reaching the offering; and (iii) unwillingness to pay, reflecting the inability to perceive sufficient value in the offering to justify its cost. Although these transaction obstacles are drawn from the social enterprise literature, they can be extended to understand the broader barriers to achieving sustainability goals. In particular, external barriers highlight the gap between stakeholder expectations and firms' strategic efforts to contribute to sustainability goals (Norris, 2024). Fig. 1 provides a visual summary of the barriers to sustainable business model innovation, integrating internal and external challenges.

Acknowledging the existence of transaction obstacles to sustainable business model innovation does not make them easier to overcome. In this context, George et al. (2021) argue that technology can address grand challenges, defined as "specific critical barriers whose removal would significantly help solve globally important societal and/or environmental problems" (p. 1001). External barriers, such as transaction obstacles to sustainable business model innovation, represent such grand challenges related to societal issues. Therefore, addressing these barriers is critical for firms to successfully implement sustainable business model innovation (Seelos et al., 2023). The literature on business model innovation often highlights the benefits of leveraging existing and emerging technologies to drive innovation. For example, Miehé et al. (2023) discuss how connectivity technologies enable greater collaboration between firms, thereby increasing co-created value. Gambardella and McGahan (2010) highlight the role of general-purpose technologies in enabling upstream firms to adopt licensing-based revenue models with downstream partners, facilitating profitable business model innovation. Li (2021) examines the potential of digital technologies to drive business model innovation in creative industries, which are often characterized by human interaction and analog processes. Autio et al. (2018) extend this perspective by highlighting how digital artifacts can serve as a source of ecosystem-based business model innovation by creating new opportunities for action, i.e., technological affordances.

A growing body of research is also beginning to examine the role of technology in advancing sustainability goals. Recent studies have explored the role of mobile communication technologies in driving sustainable business model innovation in emerging economies (Yunus et al., 2010) and their ability to foster sustainable value creation (Rakshit et al., 2021; Schilling and Seuring, 2023); blockchain technology as a driver contributing to the SDGs by reducing transaction costs in economic exchanges enabled by smart contracts and expanding access to knowledge through tokenized information (Calandra et al., 2023; Dal Mas et al., 2023; Rakshit et al., 2022); machine learning as a tool for reducing CO2 impact in multi-sided platform businesses (Haftor et al., 2021); and the use of artificial intelligence-powered knowledge management systems to advance SDG 12 (responsible consumption and production) (Di Vaio et al., 2020).

Despite this evidence, the relationship between business model innovation, sustainability, and technology is often treated as a "black

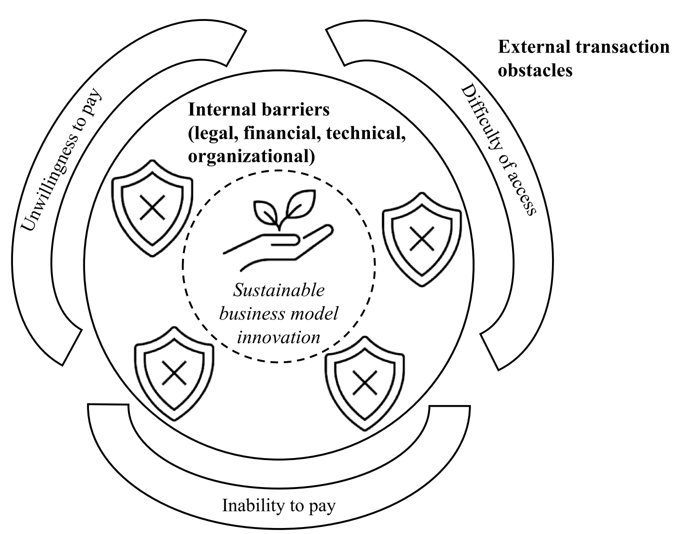

Fig. 1. Barriers to sustainable business model innovation
(Source: Own elaboration based on Geissdoerfer et al., 2023; Santos et al., 2015).

box" in the literature, with limited exploration of how and why technology helps firms overcome barriers to implementing sustainable business model innovation. Therefore, this study aims to respond to George et al.'s (2021) call for a deeper exploration of the relationship between technology and the achievement of societal goals. While existing research acknowledges the importance of technology, we lack a detailed understanding of how technology can actively facilitate sustainable business model innovation. To address this gap, we follow Haessler et al. (2022) and adopt a technology perspective to explore the specific mechanisms through which technology can help firms overcome barriers to sustainable business model innovation. Specifically, we use affordance theory (Gibson, 1977) to unpack the relationship between business model innovation, sustainability goals, and technology.

2.2. *Opening the black box: the role of technology affordances and space technology*

Affordance theory (Gibson, 1977) provides a valuable theoretical lens through which to explore technology-enabled opportunities. Rooted in sociology (Hutchby, 2001), affordance theory shifts the focus from the intrinsic properties of objects to the opportunities they enable. This perspective emphasizes the dynamic relationship between the object, its environment, and the agents who interact with it (Gibson, 1977, 1986; Norman, 1988). In the context of technology, management scholars have adapted this perspective to describe technology affordances, defined as "action possibilities and opportunities that emerge from actors engaging with a focal technology" (Faraj and Azad, 2012, p. 241). From this perspective, technology has no intrinsic value (Hutchby, 2001), but is derived from the interaction between its features, the actors who use it, and their specific purposes. This approach departs from deterministic, technocratic perspectives (Feenberg, 1991) by adopting a relational view of technology (Bailey et al., 2022; Gibson et al., 2022), which emphasizes the dynamic and evolving nature of technology as a set of relationships rather than treating it as a stable, fixed entity. Unlike traditional perspectives that view technology as a static object, the relational approach focuses on how individuals interact with technology in their ongoing practices and shape its use in organizational contexts. By integrating a practice-based lens, this perspective transcends structural views of technology and offers a more holistic understanding of its evolving role in organizations (Bailey et al., 2022; Gibson et al., 2022).

For emerging technologies whose affordances are not yet fully understood, adopting a relational view can enhance our understanding of their role in addressing complex organizational phenomena, such as sustainable business model innovation. As Autio et al. (2018) highlight in the context of digital technologies, technology affordances serve as fundamental mechanisms that enable innovation in value creation, value delivery, and value capture within organizations and ecosystems. As such, they can act as key drivers of business model innovation. This perspective goes beyond the static assumptions of task-technology fit theory (Goodhue and Thompson, 1995), suggesting that technology adoption depends on the fit between its intrinsic features and the specific tasks it supports. However, the relational view emphasizes the versatility of technology and the multiple purposes it can serve, which is particularly important when addressing grand societal challenges and sustainability goals (George et al., 2016, 2021).

Among the emerging technologies driving innovation in sustainable business models, space technology has received significant attention for its potential contributions to the SDGs (Balogh et al., 2017; Pelton et al., 2017). The rise of the New Space Economy, often heralded as the final economic frontier (Weinzierl, 2018; Vittori et al., 2022), has broadened the discussion of the far-reaching impacts of space technology across industries and contexts (Paravano et al., 2023). Space technology encompasses a wide range of innovations, including launch vehicles, antennas, telescopes, and, most notably, satellites (Pelton et al., 2017). The hallmark of the New Space Economy is the application of these technologies beyond traditional scientific and military purposes, allowing space companies to serve new private sector customer segments such as agriculture, energy, and insurance (Weinzierl, 2018).

George et al. (2021) identify space technology as a potential solution for mitigating information asymmetries among stakeholders engaged in sustainable business model innovation. Moreover, the unique features of space technology make it a key driver of sustainability (Mazzucato and Robinson, 2018; Paravano et al., 2023). To build on these insights, we adopt a technology affordance perspective (Hutchby, 2001; Leonardi, 2011) to explore the relationship between space technology and sustainable business model innovation. Accordingly, we address the following research question: *How do firms in the New Space Economy leverage the affordances of space technology for sustainable business model innovation?*

3. Method

We conducted this research as a comparative multiple case study (Eisenhardt, 1989, 2021; Gehman et al., 2018) to explore both the novelty and depth of the topic under investigation (Eisenhardt and Graebner, 2007; Eisenhardt et al., 2016), while ensuring the generalizability and comparability of our findings across multiple cases (Eisenhardt, 1991). Specifically, our study examines how 11 entrepreneurial ventures in the New Space Economy leverage space technology to drive sustainable business model innovation. To guide our analysis, we adopt a technology perspective (Haessler et al., 2022) and focus on how these ventures strategically use technology to innovate the value mechanisms of their business models (Teece, 2010) in pursuit of sustainability outcomes. These outcomes are assessed through the ventures' contributions to the SDGs, as outlined in the 2030 Agenda for Sustainable Development.[1]

Following Eisenhardt (2021), we situated our study in the context of new space entrepreneurial ventures to better understand the phenomenon under study. Entrepreneurial ventures are typically less complex than established organizations due to their smaller size, which increases transparency when studying phenomena such as business model innovation. Furthermore, these ventures often play a pivotal role in emerging industries (Hannah and Eisenhardt, 2018), such as the New Space Economy. These characteristics make them ideal cases for observing how ventures use technology in their business models to promote sustainability, and thus paradigmatic examples of the phenomenon in question. To assess sustainability outcomes, we use the 17 SDGs (Pelton et al., 2017) and their 169 sub-targets as a practical proxy. These sub-targets provide clear, actionable descriptions of the impacts required to contribute to each SDG, ensuring that we can assess the ventures' contributions to these global goals.

The sample selection process consisted of three steps: (i) identifying the pool of entrepreneurial ventures leveraging space technologies; (ii) analyzing how these ventures use space technologies to contribute to one or more of the 17 SDGs; and (iii) conducting outreach to invite participation in the study. In the first step, we used public databases such as Pitchbook, Crunchbase, and Dealroom to identify relevant ventures using keywords such as "space," "satellite," "remote sensing," "space economy," and "Earth observation." The first author carefully reviewed each venture's description and verified the use of space technology through additional sources, including official websites. This process resulted in the identification of 497 entrepreneurial ventures worldwide that use space technology as a core component of their business models. In the second step, we analyzed the ventures' websites and related news stories to classify them based on the SDGs they addressed. Many ventures contributed to more than one SDG. This approach is consistent with Eisenhardt's (2021) recommendation to select cases where the phenomenon of interest is likely to occur. All 497 ventures identified used space technology to address at least one SDG. In the final step, we

[1] From the United Nations' website: https://sdgs.un.org/2030agenda.

contacted the top 40 entrepreneurial ventures based on the number of SDGs they addressed. We introduced the purpose of the study and invited them to participate. Ultimately, data were collected from 11 ventures that agreed to participate.

To ensure generalizability, we selected ventures that varied in number of employees (indicating size), external funding received (indicating maturity), and industries in which their customers operate (indicating scope). While most of the ventures are based in North America and Europe (9 of 11), two are based in other regions. This distribution reflects the current entrepreneurial landscape of the New Space Economy. As noted by Bryce Tech (2023), North America and Europe have historically dominated space activities since the 1960s and attracted significant investment in the early stages of the New Space Economy. Although countries such as China, India, and Japan have ramped up space activities since the late 2010s, their ventures have not yet achieved international competitiveness. Therefore, our final sample of 11 New Space Economy ventures is diverse in age, size, geographic location, funding, and industry focus (see Appendix A).

3.1. Data collection

Our study draws on a significant amount of primary and secondary data from the 11 entrepreneurial ventures in our sample. To increase the robustness of our findings (Eisenhardt, 1989) and ensure the accuracy of the information provided by informants, we used a combination of interviews and archival sources, as well as data triangulation (Goffin et al., 2019) to mitigate recall bias.

Primary data were collected through three rounds of in-depth, semi-structured interviews with the top management and founding teams of the selected ventures. We focused on informants at the strategic level to gain comprehensive insights into the history of each venture, starting with its early activities and key strategic decisions. These informants were typically responsible for managing relationships with external stakeholders, while other colleagues focused primarily on technology development. In the first round of interviews, we asked broad, exploratory questions to understand the structure of the ventures' business models and the motivations behind their decision to leverage space technology. Based on the findings from the first round, we conducted a second round of interviews to explore in more depth how the use and features of space technology enabled the ventures to contribute to their sustainability goals. A third round of interviews was conducted with a subset of informants when additional information was needed or when significant changes occurred within the ventures. Throughout all interviews, we allowed flexibility to explore emerging concepts through open and iterative discussions (Eisenhardt, 2021). We conducted 27 interviews between November 2020 and October 2021 (first round September 2020; second round April 2021; third round October 2021), with each interview lasting between 30 and 60 min. Interview questions included: "Why did you decide to use space technology?", "How do the features of space technology influence your venture's activities?", and "How does space technology enable your venture to contribute to sustainability goals?"

All interviews were recorded and transcribed, resulting in 1486 min of audio and 217 pages of transcripts. To supplement our findings and reduce potential bias, we triangulated our interview data with additional sources, including public interviews (e.g., online videos and podcasts), field notes from public events such as webinars, conferences, and workshops where venture representatives spoke, and archival data from official websites, press releases, LinkedIn posts, and public databases. We also maintained ongoing communication with informants via email to validate the information collected, clarify ambiguities, and address follow-up questions that arose during data analysis. Table 1 provides a summary of the data sources.

Table 1
Data sources and type.

Data source	Type & number	Original data source
Primary sources		
Semi-structured interviews	**27 semi-structured interviews**	**Informants**
	Alpha (3 interviews)	Co-Founder & CEO
	Beta (2 interviews)	CEO
	Gamma (3 interviews)	Co-Founder & CEO
	Delta (3 interviews)	Vice President, Sales & Marketing
	Epsilon (2 interviews)	Co-Founder & CRO
	Zeta (3 interviews)	Co-Founder
	Eta (2 interviews)	Co-Founder & CSO
	Theta (3 interviews)	Co-Founder & CEO
	Iota (2 interviews)	Co-Founder & COO
	Kappa (2 interviews)	Co-Founder & CEO
	Lambda (2 interviews)	CEO & Chairman
Asynchronous communication	103 emails	Informants
Secondary sources		
Archival and public data	314 internet pages	Official websites, LinkedIn pages, press articles
	12 public reports	UNOOSA reports, McKinsey Space4Sustainabilty report, Morgan Stanley Space Economy Report (non-exhaustive list)
	17 public interviews	Informants, other entrepreneurial venture employees
	33 public database entries	Funding, governance, and demographic information about the ventures (e.g., Crunchbase, Pitchbook)
Participant observation	18 public events 244 pages of fieldnotes	European Space Agency webinars held by experts and/or informants, workshops organized by research centers

3.2. Data analysis

Following Eisenhardt and Graebner (2007), our data analysis began with the creation of case vignettes for each venture, which facilitated both understanding and comparability across cases. The first two authors then iteratively compared case information to derive aggregate constructs and variables, providing a comparative perspective, a key strength of the multiple case study approach (Gehman et al., 2018). Our primary focus was to understand how entrepreneurial ventures leverage space technology and its key features in the value mechanisms of their business models to contribute to sustainability goals.

To analyze the data, the first two authors independently coded the data collected from each case using open and axial coding techniques (Corbin and Strauss, 1990). We used the informants' own words to generate codes to ensure that the data analysis was grounded in the informants' perspectives. We followed the Gioia et al. (2013) template for qualitative data analysis, which included three steps: (1) translating the informants' words into first-order categories that synthesized the core concepts expressed; (2) iteratively comparing and aggregating these concepts into second-order themes that involved a higher level of abstraction; (3) grouping the second-order themes into overarching dimensions that aligned with existing theoretical frameworks. Although we were mindful of prior theoretical concepts, the coding process alternated between synthesizing and abstracting informants' reports and interpreting them in the light of existing theory (Gioia et al., 2013). Ultimately, we organized the second-order themes into three overarching dimensions consistent with established theory: (1) space technology features; (2) transaction obstacles to sustainability; and (3) sustainable business model innovation. The final data structure is presented in Appendix B, and a set of supporting quotations for each coding dimension is provided in Appendix C.

Through this structured analytical approach, we were able to

Table 2
Description of cases.

Venture Name	Description of sustainable business model innovation and the role of space technology	SDGs addressed
Alpha	Alpha developed a dashboard to gather insights on crop production, targeting previously excluded farmers in North America and Brazil. The service is offered through a low-cost subscription model with a freemium version that can be customized by field area. The accuracy of space data is key to providing a value-added service to low-income customers. By acquiring free data from publicly owned constellations, the venture can offer a freemium version of the service and reach more potential customers.	Alpha addresses the agricultural value chain by driving precise decision-making, using satellite space data and artificial intelligence, in line with SDG target 2.3, which aims to increase agricultural productivity and the income of small-scale food producers. By providing insights that help farmers improve their operations, increase revenue, and protect the environment by reducing chemical use, waste, and carbon emissions while increasing yield efficiency, Alpha addresses SDG target 12.4, which focuses on sustainable production and consumption patterns. In addition, Alpha's efforts to optimize water use, monitor irrigation, and leverage AI and machine learning tools align with SDG target 6.4, which aims to significantly increase water use efficiency across all sectors and ensure sustainable freshwater extraction and delivery to address water scarcity.
Beta	Beta captures data on the progress of development projects (i.e., buildings) for development organizations in Africa. It uses open source data provided by the European Space Agency and passes on some of these input cost savings to the end customer. They use the accuracy of space data to provide a value-added service to customers with limited budgets. By acquiring free data from publicly owned constellations, the venture can offer a freemium version of the service, reaching more potential customers.	By leveraging satellite data and artificial intelligence, Beta supports sustainable agriculture (SDG 2) through crop monitoring and disaster management for all communities and cities (SDG target 11.1) using satellite imagery for disaster response, contributing to the integration of climate change measurements into plans, strategies, and policies (SDG target 13.2) by monitoring environmental changes.
Gamma	Gamma provides a machine learning API for mapping informal settlements and agricultural fields, targeting customers such as development banks and large agribusinesses in low-income areas of Argentina. They use space technology to overcome the lack of terrestrial infrastructure and reach previously excluded customers in remote areas where other technological alternatives are not economically viable to install.	Gamma focuses on the use of satellite observation data and artificial intelligence to address various SDGs. Through the use of Earth observation data, Gamma contributes to better understanding and monitoring the interactions at the food-water-energy nexus, which aligns with SDG target 2.3, which aims to double agricultural productivity and income of smallholder food producers. In addition, their initiatives support SDG 4 on quality education, SDG 9 on industry, innovation and infrastructure, and SDG 17 by fostering industry partnerships and contributing to education programs through space technology.
Delta	Delta provides a carbon emissions monitoring service to methane-emitting private companies, governments, and regulatory agencies, using customized satellites and the data they produce as key resources. The use of customized and accurate space-based data technologies allows Delta to deliver a unique value proposition to stakeholders who are highly sensitive to climate issues.	Delta plays a critical role in monitoring greenhouse gas emissions from space, which aligns with SDG target 13.2 aiming to integrate climate action into national policies, strategies, and planning. By providing high-resolution data on global greenhouse gas concentrations, with dashboards that can identify specific emitting infrastructure, Delta encourages companies to adopt sustainable practices and integrate sustainability information into their reporting cycle. In addition, Delta's technology helps identify sources of methane emissions, which is critical for climate action and aligns with SDG target 13.3 focused on improving education, awareness, and human and institutional capacity for climate change mitigation.
Epsilon	Epsilon provides property-level hazard risk information to insurance companies that cover infrastructure against the risk of natural disasters. Using a proprietary database that is constantly updated with triangulated data from US government satellite data and other types of data, leveraging the network of individual partners (developers). By combining proprietary data with freely available space data, Epsilon delivers an economically affordable and valuable value proposition to the venture's stakeholders.	Epsilon contributes to the 169 sub-targets by focusing on disaster risk reduction and management through the use of space-based technologies. By leveraging satellite data and advanced analytics, Epsilon plays a critical role in contributing to the SDGs related to disaster resilience, such as SDG 11 (sustainable cities and communities) and SDG 13 (climate action). Its initiatives aim to strengthen early warning systems, improve disaster response strategies, and mitigate the impact of natural hazards on communities, in line with the broader SDGs.
Zeta	Zeta provides an insurance technology platform for micro-insurance and a supply chain risk platform targeting micro-insurance and food companies mostly in developing countries. It uses free historical satellite data for temporal analysis (e. g., ESA Sentinel), as well as volunteers to validate (and reward) the results of the algorithm. The use of free data from space technology enables the design of an economically affordable value proposition to reach previously excluded stakeholders in developing countries.	By providing micro-insurance solutions to smallholders in Indian regions, Zeta aligns with SDG target 1.5, which aims to promote the resilience of low-income and vulnerable people. By using satellite observation data to create index-based risk models, Zeta addresses SDG target 2.3, which aims to double agricultural productivity and the income of small-scale food producers. In addition, Zeta's efforts support SDG target 13.1 by increasing farmers' resilience and adaptive capacity to climate-related hazards and natural disasters, contributing to sustainable development in line with the SDGs.
Eta	Eta focuses on providing a weather forecast alert service to farmers in West Africa, using freely available satellite data from EUMETSAT and NOAA, integrated with information provided by a network of African collaborators to train the ultimate forecast model. They price each SMS on request through the offer of mobile operators, or the possibility to buy the service for a certain period of time. The use of free data from space technology allows Eta to create a value proposition that targets stakeholders in developing countries that were previously excluded.	By providing accurate weather forecasts in emerging economies through satellite data, Eta supports various SDGs including SDG 2 (zero hunger) by helping farmers plan their agricultural activities, SDG target 13.3 (climate action) by improving education and awareness on climate change mitigation through monitoring, and SDG target 1.5 (no poverty) by supporting disaster preparedness and response in poor communities.
Theta	Theta uses high-resolution satellite imagery analyzed with artificial intelligence technologies to assess the extent, health, and carbon storage capacity of forests. This approach allows the venture to accurately and efficiently monitor and quantify forestry activities at scale. The use of high-precision space data allows Theta to create a value proposition that is extremely valuable and that customers are willing to pay for.	Theta's measurements related to forest monitoring allow for the measurement of carbon sequestration and facilitate carbon offset projects that can advance the integration of climate action into national policies, strategies, and plans (SDG target 13.2), as well as promote mechanisms to increase capacity for effective climate change planning (SDG target 13.b) using space historical data. In addition, forest conservation is directly linked to SDG target 15.2 by promoting the implementation of sustainable management of all types of forests and halting deforestation.
Iota	Iota provides satellite internet connectivity services to various African industries and governments. It uses a constellation of proprietary satellites that have been in orbit for a long time and a network of local technicians, and a revenue model of a fixed monthly fee for unlimited access or pay-per-use for each gigabyte (mainly tariffs). The use of proprietary space infrastructure that delivers high quality signals	Through satellite technology, Iota provides internet access to remote and underserved areas, with specific projects that enable inclusive quality education (SDG 4), bridge the digital divide (SDG 9), and support disaster management and humanitarian assistance by enabling coordination (with satellite signals) during emergencies (SDGs 1, 11, 13).

(*continued on next page*)

Table 2 (*continued*)

Venture Name	Description of sustainable business model innovation and the role of space technology	SDGs addressed
	without the need to install ground infrastructure allows Iota to create a value proposition that targets previously excluded stakeholders in Africa.	
Kappa	Kappa provides affordable connectivity through a hardware product and a data service component, targeting users in remote or rural areas. It uses a network of proprietary small satellites and associated data as a key resource (low-cost satellites and low-cost service). The use of a proprietary space infrastructure that delivers high quality signals to portable devices without the need to install massive ground infrastructure allows Kappa to create a value proposition that can reach previously excluded stakeholders in various undeveloped areas of the world.	Kappa improves connectivity and communication through its satellite technology, which aligns with SDG target 9.1 aimed at developing reliable and sustainable infrastructure to support economic development and human well-being. By providing satellite services that increase access to information and communication technologies, Kappa contributes to SDG target 9.3, which focuses on increasing access to technology for underserved communities. In addition, their initiatives support SDG target 4.4 by increasing access to quality education through improved connectivity in remote areas, demonstrating how space technology can positively impact multiple SDGs simultaneously.
Lambda	Lambda offers a snow-melt monitoring service aimed at energy companies concerned about potential avalanches and flooding. It uses different types of data providers (e.g., European Space Agency, Swiss Energy Agency) whose data is originally integrated and displayed in a proprietary dashboard. By combining proprietary data with freely available space data, Lambda creates a value proposition for stakeholders that would otherwise be impossible to obtain. Its revenue model is based on a SaaS model that leverages open source, free space data.	Lambda's focus on leveraging advanced technologies to facilitate this transition aligns with SDG target 7.2, which aims to increase the share of renewable energy in the global energy mix. By providing innovative solutions that increase the efficiency and sustainability of energy production, Lambda supports SDG target 9.4, which aims to modernize infrastructure and transform industries to make them sustainable. In addition, Lambda's commitment to clean energy and environmental sustainability aligns with SDG target 13.2, which aims to integrate climate action into national policies, strategies, and planning.

identify both similarities and differences across cases within these dimensions. This comparative analysis generated new insights from the data (Eisenhardt, 1989), culminating in the development of an interpretive model that illustrates how space technology enables entrepreneurial ventures to overcome transaction obstacles and implement sustainable business model innovations. By integrating the space technology features with transaction obstacles to sustainability, our model identifies three key space technology affordances that facilitate sustainable business model innovation.

4. Findings

Our study of 11 entrepreneurial ventures in the New Space Economy provides valuable insights into how these firms leverage the affordances of space technology to drive sustainable business model innovation. Table 2 summarizes the key characteristics of each of the ventures included in our study. The following sections present our comparative analysis of the 11 cases, organized conceptually (Berends and Deken, 2021). First, we identify the features of space technology that these entrepreneurial ventures use to drive innovation in their business models. Second, we explore the mechanisms that link their business model innovations to sustainability outcomes, with a particular focus on how space technology helps overcome transaction obstacles that impede sustainable innovation (Santos et al., 2015). Consistent with the approach advocated by Gioia et al. (2013), we treated informants as knowledgeable agents and used rich qualitative data that emphasized their original words (representative quotes supporting the data structure dimensions are provided in Appendix C).

4.1. Space technology as sharpshooter: leveraging accuracy to overcome unwillingness to pay

4.1.1. Space technology feature: accuracy

Satellites collect and transmit data over large areas of the Earth with very high resolution and low latency. This high-resolution imagery allows for the identification of minute details, enhancing space technology's ability to monitor changes in landscapes, infrastructure, and environmental conditions. The accuracy of space technology is particularly valuable for applications such as urban planning, agriculture, and environmental monitoring. For example, Alpha uses high-resolution satellite imagery to collect data on crops in North and Latin America, processing it through a machine learning algorithm to provide insights that help farmers make decisions, such as information on irrigation levels and detecting uncontrolled vegetation growth that could harm crops. Similarly, Epsilon combines satellite imagery with other databases, such as municipal land records, to create property-level risk indices that support deals in the US real estate industry. Satellites with short revisit times can capture images of the same location multiple times over a period of time. This feature is critical for monitoring dynamic situations such as natural disasters, climate change, and urban development. The ability to frequently revisit locations improves data accuracy, provides real-time insights, and enables rapid response. To this end, Gamma uses the high revisit time of satellite data to monitor informal settlements, generating valuable information for municipalities and public agencies focused on urban development. As Epsilon's CEO noted:

> "*You have the possibility to select the exact latitude and longitude of the data you want to capture, with very high resolution.*" (CEO, Epsilon)

Satellite data is often accessible through digital portals managed by public institutions (e.g. the European Commission and the European Space Agency's portal for the Copernicus constellation), making it a transparent and certified source for third parties. This institutional legitimacy helps build greater trust in the customer-supplier relationship. For example, Theta offers a carbon storage monitoring service. With the growing interest in environmental, social and governance issues, the need to measure and certify carbon footprint initiatives has become increasingly important for companies. However, most traditional methods of assessing carbon footprints rely on human measurements, and the adoption of developed standards is still limited. As the CEO of Epsilon shared, satellite data offers promising opportunities to address these challenges:

> *"Using satellite data allows us to bring more transparency and trust to the relationship, but also allows the relationship to happen in the first place."* (CEO, Epsilon)

Another key feature of space technology is the ability to access historical archives of space data, a significant advantage over other alternative technologies.

> *"With satellites, like with Sentinel, we can go back years … Even though we've only been around for a year or two, our datasets go all the way back to 2003, when this class of imagery started to be captured. So, if we develop a model that is validated on today's data, it gives us a huge amount of value and the time to index and develop trends over time."* (CEO, Beta)

> *"Space technology allows you to have real-time (or almost real-time) data of what's going on in the world. Also, you can look at what happened in the past."* (CEO, Theta)

Indeed, users can access data collected by public satellite constellations over years, sometimes decades, providing the opportunity for analysis and insight from a longitudinal perspective. For example, Lambda predicts snow-related phenomena such as avalanches and floods. While weather data must be triangulated, Lambda's informants emphasized that the ability to access satellite imagery showing the fall and distribution of snow in past years is essential. This feature allows Lambda to train predictive models based on historical analysis and to account for the effects of climate change over time.

> *"When we start a new project in a new area, space technology allows us not to start from scratch in terms of data collection. We can access over 10 years of images of the area, captured every 2–3 days, and freely retrievable. This information allows building basic indices about the evolution of snow distribution over time. Thus, for each new project, before collecting other data, we train our models using this asset."* (CEO, Lambda)

4.1.2. Overcoming unwillingness to pay

Space technology is characterized by features such as high resolution, short revisit times, public access, and historical archives. These attributes ensure exceptional accuracy in the information collected compared to ground-based methods, enabling the ventures in our sample to develop innovative products and services. However, all of our cases highlight how accuracy has been critical to their growth, particularly in entering and targeting specific customer segments that face significant obstacles to finding solutions to their needs. Despite the potential benefits that new products or services can offer, some customers are reluctant to adopt them because they do not see their value compared to existing solutions. Our findings indicate that this problem is particularly prevalent in emerging markets (e.g., East Africa), where potential customers tend to be price-sensitive and skeptical of products and services based on innovative technologies, especially if their performance is unknown or unproven.

> *"We are working with customers in several countries and our first barrier is to understand what they need on the one hand, and what they are willing to buy on the other. And so this dialogue sometimes takes longer than it should."* (CEO, Zeta)

> *"We've opened an African office with local personnel to show them things. We assume we understand the problems that people are facing or how to design a solution that helps to address those problems, and in reality, we don't. We're outsiders, we are, we just lack the kind of the context and understanding of what it means to be someone who lives in these locations and experiencing these categories of problems."* (CEO, Beta)

If these customers have already adopted other solutions to meet their needs, convincing them to consider new alternatives becomes a challenge. For example, farmers need to monitor crop health to maximize yields or assess weather conditions to protect their infrastructure.

Our findings show that the multiple sources of high accuracy inherent in space technology are key to targeting these customer segments. First, the resolution of space data and its frequent updates provide a significant improvement over the other solutions these customers often use (e.g., aerial imagery). In some cases, potential customers do not use alternative technologies to meet their needs and instead rely on human measurement and knowledge (e.g., predicting weather conditions based on experience and assessing wind currents). However, the improvements enabled by more accurate information are often not enough to convince these customers to adopt a new solution, so other features of space technology that ensure accuracy become critical to overcoming this obstacle.

In this context, the ability to leverage historical data collected by space technology becomes a key factor in overcoming the adoption difficulties faced by these customers. Specifically, some of the entrepreneurial ventures we analyzed reported that they set up demonstrations of their innovative products and services for potential customers by predicting events that customers were already familiar with because they had occurred in the past. For example, Alpha showed prospective customers images of their agricultural fields before and after a period of severe drought, providing visual examples of how their solution could have supported crop optimization to mitigate the effects of the drought. By demonstrating the potential benefits in familiar conditions, customers were able to see firsthand the value the solution could bring. In addition, some informants noted that the transparency of space data provided by public institutions was a key feature in encouraging adoption by customer segments that would otherwise be reluctant. The legitimacy conferred by association with highly trusted institutions (e.g., the European Space Agency) makes customers more open to considering products and services based on data from technologies such as satellites that are owned and managed by recognized organizations.

In summary, our cases show that the accuracy of space technology drives the design of innovative products and services that overcome obstacles related to the perceived value mismatch between the improvements offered by new solutions and their cost (i.e., unwillingness to pay), particularly in emerging markets. By addressing this mismatch, space technology enables businesses to create value while contributing to the contribution to various goals outlined in the Sustainable Development Agenda, resulting in sustainable value creation. Specifically, facilitating access to basic technologies for poor and underserved populations aligns with SDG target 1.4 (eradicate poverty). This, in turn, supports the adoption of sustainable and resilient agricultural practices in emerging markets (SDG target 2.4), optimizes water use in water-scarce regions (SDG target 6.4), and provides informed access to renewable energy sources, helping to diversify the global energy mix (SDG target 7.2). For example, Lambda directly supports countries that lack adequate infrastructure (e.g., New Zealand) in planning their transition to clean energy.

> *"Providing user-friendly dashboards displaying the possible sources of renewable energy is fundamental. Satellite maps break barriers, making firms and government bodies realize what actions for their energy transition policies they can take."* (CEO, Lambda)

Through these findings, we observe that the accuracy of space technology enabled the ventures to innovate their value creation formula and overcome customers' unwillingness to pay for their services, ultimately enabling them contribute to significant sustainability objectives. Building on these insights, we argue that space technology functions as a sharpshooter, acting as a crucial affordance that firms can leverage for sustainable business model innovation.

4.2. Space technology as a Trojan horse: leveraging ubiquity to overcome difficulty of access

4.2.1. Space technology feature: ubiquity

Space technology is also unique in its ability to collect data from multiple locations in a very short period of time. Unlike other technologies, satellites can collect large-scale data about different regions of the Earth, often on a global scale. Systems such as GPS, GLONASS, and Galileo use constellations of satellites to provide global positioning and navigation information. As one of our informants pointed out, the ubiquity of space technology is a particularly distinctive feature.

> *"You can look at Earth from a distance. So, you can cover more ground, and look at larger areas, and you can also look at the whole world."* (Vice President, Delta)

Industries ranging from transportation and logistics to agriculture and surveying benefit from accurate global positioning data and the ubiquity of satellites orbiting the Earth. For example, Iota provides internet access services and is able to cover diverse geographic areas with a small fleet of proprietary satellites. Kappa, on the other hand, developed a proprietary payload that is installed on orbiting satellites, coupled with a physical receiver device on the ground. Wherever the receiver is on Earth, the satellite payload can determine its precise location in real time. Its primary application is in maritime logistics, where customers need to continuously monitor the position of their goods for insurance purposes. Because the data source is the orbiting satellite, often owned by a third party, there is minimal need for physical infrastructure on the ground. One of the key benefits of this feature is the ability to access rural areas that are often inhospitable or dangerous to humans.

> *"The problem for smallholder farmers is that they are in very remote places. Usually in places where there are is real infrastructure."* (CEO, *Zeta*)

This underscores the powerful benefits that agriculture can reap from the adoption of space-based solutions. Delta is leveraging this feature of satellites to provide carbon emission monitoring services to methane emitting companies, governments, and regulatory agencies. The scale of such an application would be unsustainable with ground-based technologies. Collecting data on multiple areas of the globe (or even within the same region) would be much more difficult, both economically and practically, through the installation of ground sensors. In addition, having access to data on an international basis allows for the comparison and benchmarking of different situations in different regions. The ability to have unique and consistent measurements across different countries allows for a variety of applications. For example, Theta uses global satellite imagery to assess the extent, health, and carbon storage capacity of forests around the world.

Thanks to the ubiquitous nature of space technology, Theta can compare and rank different regions of the world in terms of carbon storage capacity using the same measurement tool, providing reliable insights into the policies being implemented by different institutions to mitigate climate change. Another example is Lambda: although primarily focused on avalanche and flood forecasting in Europe, it often opens up new customer relationships in areas with different climatic conditions than previous projects. The ability to access data from regions closer to the new target is therefore an invaluable source of information for Lambda, allowing it to set up activities more quickly and target a wider range of customers.

> *"We can access pretty much any region of the planet, so we can scale the business model based on space data and be global from day one."* (CEO, Lambda)

> *"We went from one country to another with our economic modeling in a very short period of time with a very small team."* (CEO, Beta)

4.2.2. Overcoming difficulty of access

As our informants underscored, ventures leveraging space technology are able to offer global and scalable value propositions from the outset. Each venture in our sample emphasized that the ubiquity of space technology enabled them to overcome obstacles that competitors often face, particularly when targeting rural areas that are difficult to reach due to inhospitable conditions, low population density, corruption in obtaining licenses, and high tariffs on importing goods. Countries in regions such as West Africa and Latin America share some of these challenges, and most of our informants identified the ubiquity of space technology as a key factor in accessing these markets. In particular, populations living in small, remote villages often lack basic infrastructure. Low population density and the difficulty of reaching these areas from urban centers often make investment in physical infrastructure economically unfeasible.

> *"In Africa, there are not many ground-based weather observations, we entered this market by using satellite derived products […] because we have access to these sorts of derived products in areas where you don't have ground observations."* (Co-Founder, Eta)

There are two main reasons for the lack of basic infrastructure in these areas. First, the cost of deploying extensive networks (e.g., fiber optic cables) in regions where climatic conditions make regular maintenance difficult is a significant barrier. This discourages providers from targeting hard-to-reach market segments because of the high recurring costs required to keep the infrastructure functional. Second, the low population density in these areas makes the potential customer base insufficient to justify the installation costs. These regions, often referred to as "market failure areas" exist throughout the world. However, in developed countries, governments and institutions often intervene to bridge the gap, ensure equality for all segments of the population, addressing market failure through public investment. For example, despite their low population density, many European mountain regions are connected to broadband internet via fiber optic cables thanks to government funding. This type of public intervention is far less common in low-income countries, where government support is generally more limited.

> *"These developing regions need to have satellites because there is no other choice. They represent profitable markets for us because the difficulty of deploying terrestrial infrastructures lowers the level of competition."* (Vice President, Iota)

In fact, Iota provides internet connectivity via satellite in five West African countries, often involving the local community in the installation and maintenance of small receivers in public buildings or private homes. Iota's team has also undertaken specific digitization and literacy projects, providing internet connectivity to primary schools in remote villages in Ghana. Another application of Iota's service is tracking and monitoring the location of scrapers in Kenya, helping the government insure them against frequent damage caused by criminal gangs opposed to the government. Another challenge to reaching countries outside established trade routes is the high cost of importing goods from overseas. While high quality technologies could provide valuable solutions to various customer needs, vendors often struggle to enter these markets at economically viable prices. In many cases, alternatives to satellites require the importation of large pieces of physical infrastructure via freight transport, incurring significant import duties.

> *"One problem is importing goods, because of the customs duties … Customs duties in African countries are extremely high. If a piece of equipment costs $500, I will affect the local partner if we have to pay the same $500 for custom duties if, at the end of the day, the price is $500 from the factory, then you have to add $500 for transportation, shipping, and at least $500 for customs duties. In the end, to buy one piece of equipment here, the final price is tripled."* (Vice President, Iota)

Space technology eliminates the costs associated with transportation and import duties. No equipment needs to be imported or installed in the target country, as space data can be accessed from anywhere in the world without the need for a large physical infrastructure on site.

In summary, our findings show that the ubiquity of space technology is a critical feature for entrepreneurial ventures to deliver value propositions to customer segments that are otherwise difficult to reach for various reasons. This ability to penetrate underserved markets enables the ventures to contribute to several goals outlined in the Sustainable Development Agenda, resulting in sustainable value delivery. In particular, reducing the so-called "digital divide" by providing access to information and communication technologies is an important milestone (SDG target 9.5c). This also opens the door to other applications that support other SDGs. For example, connectivity enables streaming classes in remote villages where school buildings are often limited to more populated areas, ensuring equal and more widespread access to education (SDG 4). More generally, improved connectivity fosters new entrepreneurial initiatives and the development of local communities in emerging economies (SDG 11). This idea is summed up by Iota's Vice President:

"Give the population access to the internet, and this is a general impact. We're working with local people, with local entrepreneurs, small businesses in general. In fact, we help them to develop the business … to develop a system for their business, profitable business." (Vice President, Iota)

Through these findings, we observe that the ubiquity of space technology enables entrepreneurial ventures to innovate their value delivery model and overcome customers' difficulties in accessing their services, ultimately allowing the ventures to contribute to significant sustainability goals. Based on these considerations, we argue that space technology acts as a Trojan horse in this interaction, serving as a powerful affordance that firms can leverage to implement sustainable business model innovations.

4.3. Space technology as a piggy bank: leveraging low cost to overcome the inability to pay

4.3.1. Space technology feature: low cost

Our findings also suggest that the low cost of satellite data is a critical feature for entrepreneurial ventures. Modern space satellites and the data they produce are designed to integrate seamlessly with other advanced technologies, such as artificial intelligence, machine learning, and Internet of Things devices. This integration allows private companies to leverage existing, widely adopted technologies to provide satellite-based services, minimizing the need for additional investment in complementary technologies. For example, weather and emergency alerts generated by satellites can be easily accessed directly on a smartphone.

"The space industry has evolved greatly in the last 10 to 15 years, and it is now possible to build and launch satellites that are much smaller and cheaper than traditional ones." (Vice President, Delta)

"The small size of the new satellites enables them to be built, launched, and maintained less expensively than other constellations." (CEO, Kappa)

These findings demonstrate that the new generations of satellites are more cost effective than traditional designs over the entire lifecycle of the asset. The cost reduction is even more pronounced for satellite data (than satellite infrastructure), where individual data can be transmitted to and from satellites without the need to install and maintain ground infrastructure, which often accounts for the majority of costs, as in the case of communications. In addition, as noted above, both the US and Europe have made satellite imagery available to all citizens through public platforms, effectively providing free access to any user.

"We use open-source satellite data from the European Space Agency. This is a huge advantage." (CEO, Beta)

For example, satellite imagery from the Copernicus constellation (owned by the European Space Program and operated by the European Space Agency) can be freely downloaded by anyone. While the raw data is available for free, other platforms (both semi-public and private) offer the same data processed and ready to use for a fee. This access to free input data allows new ventures to focus their investments on high-quality data transformation. As a result, the primary cost associated with offering satellite-based value propositions is data processing, while acquisition costs are close to zero. In addition, the absence of physical infrastructure, coupled with the inherent intangibility of data signals, allows applications to be operated remotely in hard-to-reach areas without the need for local staff, resulting in further cost savings.

"Since we don't have to deploy personnel on the ground, it's obviously a lot cheaper […] In turn, that allows us lower the price." (Vice President, Delta)

Another advantage of satellite-based value propositions is the ability to customize offerings to meet the specific needs of individual customers. Because the acquisition of raw satellite signals is relatively inexpensive, new ventures have greater flexibility to work with prospective customers to develop customized solutions that meet their unique needs. New ventures can take advantage of the low cost of satellite infrastructure and data to pass on some of their savings over alternative technologies to the end customer, while retaining the ability to customize solutions for specific applications.

4.3.2. Overcoming inability to pay

Our data suggest that the ability to leverage the low costs associated with space technology has enabled most of the entrepreneurial ventures studied to access low-income markets, where customers often lack the financial means to meet their needs.

"Either because infrastructure did not exist, or existing solutions were prohibitively expensive, in some areas of the globe there is no chance to penetrate." (CEO, Kappa)

In particular, the ability to pass on some of the cost savings to the end customer is a critical factor in the adoption of satellite-based value propositions in low-income markets. Several ventures in our sample highlighted how competitors often overpriced their services and failed to address these markets effectively. For example, the CEO of Zeta explained that the availability of free satellite data allows them to serve micro-insurance organizations supporting low-income farmers in developing countries, farmers who are traditionally excluded from insurance services because such offerings are prohibitively expensive relative to their income.

"This is because traditional insurance companies have high administrative costs, high distribution costs […] very high cost of assessment, because they are still big in the traditional way of assessing, going into the field, doing sampling. When they try to scale down for micro-insurance, the costs are not really scaled down. So, in the end […] there is no value for money, really." (CEO, Zeta)

Similarly, Eta leverages the low cost of satellite communication to interact with farmers through satellite-born SMS.

"[We provide a service at] € 0.02 per SMS […] If they wanted to receive communications every day for a whole year, the price would be € 7.00 per year. A very low cost compared to, for example, the price of other inputs like fertilizer or pesticides. Something like 1 % or 2 % of the cost of that." (Co-Founder, Eta)

To capitalize on the opportunities presented by the low cost of space technology, it is critical for ventures to deliver their offerings through technologies that are already prevalent in their target customer segments, thus eliminating the need for additional financial or resource commitments. In regions with low levels of digitization, the integration of an offering into existing devices is a critical success factor for entrepreneurial ventures and their business models.

In summary, the low cost of space technology and its by-products is a significant driver of the ability of entrepreneurial ventures to deliver their services. By passing on some of the satellite data and infrastructure savings to the end user, ventures effectively target customers who would otherwise not be able to afford these services. Space technology thus acts as an enabler in the design of sustainable value capture mechanisms. This allows a wider range of potential customers to access essential services and technologies for diverse applications, in line with the affordability principle highlighted in the Sustainable Development Agenda (e.g. SDG targets 1.4, 4.1, 11.1).

"For many customers, particularly those focused on global/sustainable development and environmental research, keeping their IoT devices connected in remote areas is a necessity, but they can't afford to spend a fortune on existing satellite solutions. Kappa allows these customers to spend, on average, 4 to 20 times less on satellite connectivity. This also

means more money can be spent on the actual work they do." (CEO, Kappa*)*

These findings suggest that the low cost of space technology enables entrepreneurial ventures to innovate their value capture formulas and address customers' inability to pay for their services, in turn allowing the ventures to contribute to meaningful sustainability goals. Building on these considerations, we argue that space technology acts as a piggy bank in this interaction, representing a critical affordance of space technology that firms can leverage to implement sustainable business model innovation.

4.4. A space technology affordance view of sustainable business model innovation

Our findings illustrate that the features of satellite technology enable sustainable business model innovation in entrepreneurial ventures. Specifically, space technology enables ventures to overcome transaction obstacles that hinder sustainable business model innovation. Based on our findings, we observe that the core features of space technology (i.e., accuracy, ubiquity, low cost) enable business model innovation (i.e., value creation, value delivery, value capture) to overcome external transaction obstacles identified in prior studies for firms striving for sustainable business model innovation (i.e., unwillingness to pay, difficulty of access, inability to pay) (Santos et al., 2015). These combined mechanisms result in three key space technology affordances that firms can leverage to achieve sustainable business model innovation.

First, the accuracy that characterizes space technology enables entrepreneurial ventures to engage in innovative value creation. The value proposition based on space technology accuracy encourages customers to choose the ventures' solutions over competitive alternatives that may be perceived as less accurate or of lower quality. In this way, space technology helps ventures overcome customers' unwillingness to pay. We refer to this affordance as "space technology as a sharpshooter." The metaphor reflects space technology's ability to precisely detect and capture information, thereby providing immense value to customers and making them more likely to accept and pay for the solution.

Second, the ubiquity inherent in space technology enables entrepreneurial ventures to innovate how they deliver value to customers. This ubiquity allows firms to reach remote areas or underserved populations without the need for basic infrastructure, effectively mitigating the difficulty customers have in accessing the ventures' offerings. We refer to this affordance as "space technology as a Trojan horse." This metaphor, derived from the myth of Ulysses, symbolizes the smart and effective means by which space technology can access and deliver value to previously unreachable places.

Third, the low cost of space technology allows entrepreneurial ventures to innovate their value capture mechanisms to overcome customers' inability to pay. The relatively low cost of satellite-based services (or quasi-free access) allows ventures to offer their services to customers who would otherwise be unable to afford them. This affordability frees up financial resources for customers to meet other primary needs. We refer to this affordance as "space technology as a piggy bank."

In summary, our findings show that by leveraging the core features of space technology, entrepreneurial ventures can innovate the value mechanisms of their business model to overcome key external obstacles to sustainability, ultimately facilitating sustainable business model innovation as illustrated in the model in Fig. 2.

5. Discussion

Our findings illustrate how firms can leverage the affordances of space technology to implement sustainable business model innovation. This study contributes to the growing scholarly interest in the role of space technology in enabling firms to contribute to sustainability goals (Balogh et al., 2017; Heldt and Beske-Janssen, 2023). Complementing the extensive engineering literature that examines space technology from a technocratic perspective (Farooq and Manocha, 2024; Feenberg, 1991; Kerrouche et al., 2023), we adopt a technology affordance perspective (Leonardi, 2011) to unpack the opportunities for action that space technology creates for firms. This perspective emphasizes the role of space technology in overcoming transaction obstacles to sustainability faced by external stakeholders (e.g., customers, beneficiaries) (Faraj and Azad, 2012; Santos et al., 2015), thus enabling firms to implement sustainable business model innovations (Bocken et al., 2014; Evans et al., 2017). To conduct our research, we examined how 11 entrepreneurial ventures leveraged space technology to achieve sustainable business model innovation. Following the relational structure of technology affordances (Bailey et al., 2022), we link specific space technology features to transaction obstacles to sustainable business model innovation, uncovering three space technology affordances. Each affordance represents the relationship between a space technology feature (i.e., accuracy, ubiquity, low cost) and a transaction barrier to sustainability (i.e., unwillingness to pay, difficulty of access, inability to pay). The persistent nature of these transaction obstacles in the sustainability domain (Santos et al., 2015) highlights the relevance of the affordances we identify for addressing these barriers and contributing to sustainability goals through sustainable business model innovation.

Our findings contribute four key theoretical insights to the debates surrounding sustainable business model innovation and the New Space Economy. These insights enhance our understanding of how space technology can propel firms toward their sustainability goals while overcoming key barriers to the adoption of sustainable practices. The following sections elaborate on these contributions, the managerial implications, limitations of the study, and potential avenues for future research.

5.1. Theoretical contributions

Our study responds to calls for a deeper understanding of sustainable business model innovation (Bocken and Geradts, 2020; Snihur and Bocken, 2022) and its link to technology (Engwall et al., 2021; George et al., 2021). Using the technology affordance perspective (Bailey et al., 2022; Leonardi, 2011), we explore how the intrinsic features of space technology help firms overcome transaction obstacles for sustainable business model innovation (Santos et al., 2015). Through this link, we introduce three key space technology affordances that firms can leverage, with several theoretical contributions to the ongoing academic discourse.

First, we address the call for research on how business model innovation can support firms in contributing to sustainability goals (Snihur and Bocken, 2022; Palmié et al., 2024). Drawing on the three transaction obstacles to integrating societal goals into business models (Santos et al., 2015), we explore how the intrinsic features of space technology enable entrepreneurial ventures to overcome these obstacles. Our work enriches the broader conversation on the drivers and barriers to sustainable business model innovation (Broccardo et al., 2023; Olesson et al., 2023) by explicitly linking technology, an identified driver, to specific external transaction obstacles, a perspective largely overlooked in current studies. Although previous research has focused on barriers to sustainable business model innovation, the literature predominantly addresses how firms cope with internal organizational barriers, particularly in established firms attempting to integrate sustainability into existing business models (e.g., Bocken and Geradts, 2020; Ringvold et al., 2023). Building on George et al. (2021), who examine firms' use of emerging technologies to address grand challenges, our research highlights how sustainable business model innovation can benefit from a more nuanced understanding of technology. Specifically, through the lens of technology affordances (Bailey et al., 2022; Leonardi, 2011), we highlight firms' agency in recognizing actionable opportunities by leveraging the intrinsic features of technology to overcome external barriers, such as aligning customer needs with firm activities

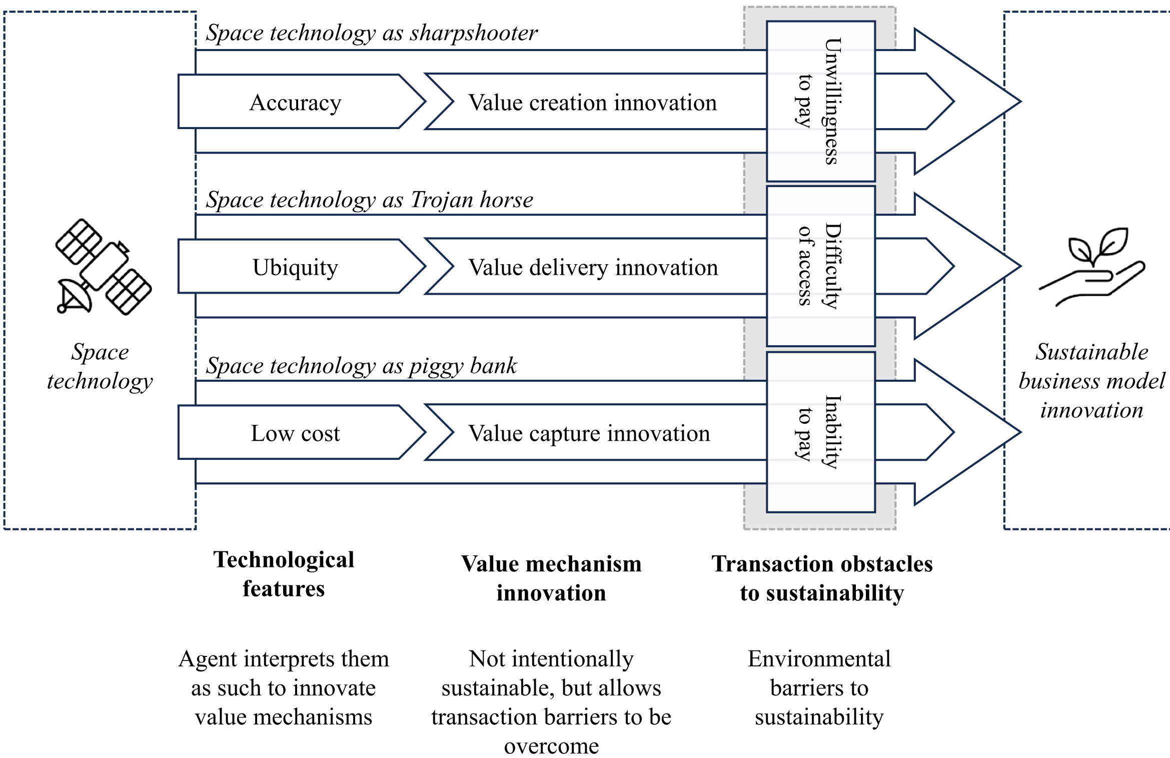

Fig. 2. A model of space technology affordances for sustainable business model innovation.

(Geissdoerfer et al., 2023; Norris, 2024). Our research also complements studies (e.g., Ringvold et al., 2023) that focus on the activities and processes that firms can adopt to integrate sustainable business model innovation into their existing models (Dhir et al., 2023). Prior studies typically consider business model innovation from a new-to-the-firm perspective, where the main challenges are internal to the firm itself (Foss and Saebi, 2018).

However, other studies have argued that firms achieve sustainable business model innovation only when they are aligned with external stakeholders who benefit from such innovation (Norris, 2024). These stakeholders are located outside the boundaries of the firm and create barriers at the industry level rather than at the firm level (e.g., bottom-of-the-pyramid stakeholders) (Angeli and Jaiswal, 2016; Iheanachor et al., 2021). Therefore, we suggest that sustainable business model innovation needs to be considered from both internal and external perspectives (Foss and Saebi, 2018; Snihur and Bocken, 2022). To this end, our study highlights how technology can support firms in addressing the underexplored external side of sustainable business model innovation, particularly in engaging with external stakeholders facing industry-level barriers (i.e., transaction obstacles), thus contributing to the emerging conversation on the demand side of business model innovation (Sanasi et al., 2024). Specifically, we show how firms can leverage specific technology features to provide value propositions that mitigate external barriers to sustainable business model innovation, thereby contributing to a more comprehensive understanding of sustainable business model innovation.

Second, by focusing on external barriers to sustainable business model innovation from a technology affordance perspective (Bailey et al., 2022; Leonardi, 2011), our study extends current knowledge in this area. While most prior studies have examined sustainable business model innovation as a result of sustainable value creation activities, as Norris (2024) points out, our study highlights the importance of considering innovation across all three value mechanisms that comprise a firm's business model: sustainable value delivery, sustainable value capture, and sustainable value creation. This comprehensive approach strengthens the connection between sustainable business model innovation and the broader business model innovation framework (Foss and Saebi, 2017; Teece, 2010). Therefore, our study advances the investigation of the inherent complexity of implementing sustainable business model innovation, which is often treated as a singular issue that firms must address (Palmié et al., 2024). Indeed, the emphasis in the literature on the organizational barriers firms face in integrating or implementing sustainable business model innovation into their existing models has predominantly focused the conversation on sustainable value creation (Bocken and Geradts, 2020; Olesson et al., 2023; Ringvold et al., 2023). However, existing definitions of sustainable business model innovation agree that it must impact multiple stakeholders to be considered truly sustainable (e.g., Bocken et al., 2014; Evans et al., 2017), which also includes the delivery of value to stakeholders and the appropriation of that value. Drawing on the technology affordance perspective (Leonardi, 2011), our research shows that firms can leverage the intrinsic features of technology to not only create value sustainably, but also to overcome the barriers that stakeholders face in receiving and appropriating that value. Moreover, by exploring how firms can use technology to overcome external barriers to contributing to societal goals, our research bridges the literatures on technology affordances and sustainable business model innovation with the expanding conversation on grand challenges (Seelos et al., 2023).

Third, our study lays the groundwork for empirical research on firms' use of space technology to contribute to societal goals, building on previous studies that have only illustrated this potential (Balogh et al., 2017; Heldt and Beske-Janssen, 2023). Specifically, we enhance the current understanding of space technology as a source of action opportunities for overcoming barriers to sustainable business model innovation by drawing on a technology affordance perspective (Bailey et al., 2022; Leonardi, 2011). This contribution helps to bring the space technology discussion into the strategic management discourse, complementing the extensive engineering literature that typically takes a technocratic view of space technology applications (Feenberg, 1991), including emerging technologies such as mobile payments in the early 2010s (Rakshit et al., 2021; Yunus et al., 2010) and, more recently, blockchain (Rakshit et al., 2022). By adopting a technology affordance perspective, we establish a clear link between technology and the value mechanisms in business model innovation (Autio et al., 2018), contributing to the discourse on the role of space technology in identifying entrepreneurial opportunities for new ventures (Lamine et al., 2021), shaping business and innovation ecosystems (Jacobides et al., 2018; Song et al., 2024), and driving the broader emergence and development of the New Space Economy (Rottner et al., 2021; Weinzierl, 2018).

Our study also advances the ongoing debate on customer value perceptions in the New Space Economy, particularly the challenge that potential customers face in assessing the benefits of space technology (Paravano et al., 2023). The technology affordance perspective we adopt emphasizes the relationship between space technology features and transaction obstacles to sustainable business model innovation (Bailey et al., 2022; Santos et al., 2015). In this regard, our study highlights the potential for firms to leverage technology affordances, focusing on the opportunities for action enabled in relation to external entities (e.g., the barriers faced by stakeholders), rather than in absolute terms. This approach links the supply-side and demand-side value of new space technology applications, bridging the New Space Economy debate (Weinzierl, 2018) with the broader and promising conversation on the commercialization of emerging technologies to create new industries (Engwall et al., 2021; Grodal et al., 2015; Haessler et al., 2022; Moeen et al., 2020), often characterized by high uncertainty that can jeopardize the future of promising sectors (Islam, 2017; Zuzul and Tripsas, 2020).

5.2. Practical implications

In addition to the theoretical contributions to the body of scientific knowledge, our study has significant implications for practice. The insights gained from our research on the interconnected relationship between space technology and sustainable business model innovation are directly relevant to entrepreneurs, managers, and policymakers. The three space technology affordances identified provide actionable guidelines for entrepreneurs and managers seeking to implement sustainable business model innovation. By leveraging these affordances, either individually or in combination, practitioners can harness the potential of space technology to contribute to societal goals. In addition, our study uses the SDGs as a proxy for the sustainable outcomes of business model innovation, providing managers and policymakers with a direct framework for understanding how space technology can help contribute to these goals.

Our study also informs policymakers by highlighting the central role that space technology can play in facilitating contributions to societal goals. Building on previous research (Trotter and Brophy, 2022), our study aligns with policymakers' interest in designing policy instruments that support sustainable business model innovation. Policymakers can use our findings on how ventures can leverage the space technology affordances for sustainable business model innovation to design informed policies and initiatives that promote the integration of space technology into broader socioeconomic development strategies.

Finally, our study addresses the emerging concern of the space sustainability paradox (Wilson and Vasile, 2023). Despite the potential for space technology to contribute to sustainability goals, both managers and policymakers must remain vigilant about the overall sustainability of space applications, including launching new space infrastructure into orbit. Industry reports (e.g., Euroconsult, 2023) predict an increase in the number of satellites launched due to their commercial applications, raising concerns about collision risks and space debris. However, our study contributes to this conversation by demonstrating how firms can contribute to sustainability goals through existing space technologies, such as long-lived public satellite constellations (e.g., Copernicus). Specifically, our research highlights the agentic role of firms (and by extension, managers and entrepreneurs) in engaging with space technology to identify actionable opportunities for overcoming transaction obstacles to sustainable business model innovation.

Our research provides valuable guidance for practical decision-making and encourages managers, entrepreneurs, and policymakers to look at existing space technology to identify previously undiscovered opportunities for action. This approach could help avoid the planning, design, implementation, and in-orbit operation of additional (and unnecessary) space technologies, thereby promoting a more efficient use of resources. By facilitating a deeper understanding of the practical applications and implications of space technology, our research contributes to contributing to sustainable outcomes and mitigating the space sustainability paradox.

5.3. Limitations and future research avenues

This study is not without limitations, which provide valuable opportunities for future research. First, our study uses a comparative multiple case study research design, focusing specifically on the New Space Economy. While our sample of entrepreneurial ventures includes firms operating in different application domains, with different demographic characteristics, and addressing multiple societal goals, caution is warranted in generalizing the findings to broader contexts and goals. Future research could address this limitation by employing larger samples and conducting comparative analyses to improve the generalizability of the findings. In particular, large-scale studies could explore the simultaneous effects of addressing both internal and external barriers to sustainable business model innovation, including both established firms and entrepreneurial ventures, as well as the performance implications of the two approaches. In addition, future research could use configurational approaches (e.g., QCA) to examine whether the simultaneous presence of multiple technology affordances and sustainable value mechanisms is necessary or sufficient to achieve a more integrated form of sustainable business model innovation (Foss and Saebi, 2018).

Second, our entrepreneurial ventures are predominantly based in Europe and the US. While this reflects the current distribution of the majority of entrepreneurial ventures in the New Space Economy – particularly those contributing to sustainability goals – since the space race began in the 1960s (Bryce Tech, 2023), future studies could examine new ventures in other regions of the world.

In addition, our study is exploratory in nature and does not aim to follow an inferential logic to assess the performance outcomes of using space technology affordances to implement sustainable business model innovations. Future research could further explore this aspect by investigating the impact of space technology affordances on sustainability performance and assessing the efficiency and effectiveness of using space technology to contribute to specific societal goals. In this study, we use the SDGs as a proxy for sustainability goals to observe the sustainable impact of a given business model at a specific moment in time. Although it is challenging to objectively measure the impact of the actions taken by the entrepreneurial ventures in our study, future studies could adopt a longitudinal research design to observe whether space technology affordances for sustainable business model innovation have a specific impact on the SDGs and track the evolution of their impact over time to complement the findings of this study.

Finally, our study is limited to entrepreneurial ventures in the New Space Economy. Future studies could explore whether and how the intrinsic features of space technology can lead to other space technology affordances beyond sustainable business model innovation. Given the inherently relational nature of the concept of affordance, our conceptual model is based on the relationship between space technology features and transaction obstacles to sustainable business model innovation, resulting in a sustainability-oriented model. However, we do not exclude the possibility that the same (or different) space technology features could enable additional space technology affordances. Research in this direction could further contribute to the nascent New Space Economy conversation from a technology affordance perspective, focusing on affordances related to for-profit purposes. For example, the asset-light nature of satellite technology could attract the attention of international business scholars interested in exploring technology features that facilitate more cost-effective cross-border expansion.

On the other hand, one of the main novelties of the New Space Economy is the way new entrepreneurial ventures have been able to target new customer segments with innovative applications based on the intrinsic features of space technology. Future studies could explore whether and how the technological features that characterize other technology-driven industries also lead to sustainable business model innovation. For example, the low latency of 5G connectivity enables telecom companies to offer applications such as telemedicine or autonomous driving, thereby targeting new customer segments. Similarly, information technology companies are now leveraging quantum computing features to develop new applications in drug discovery and materials science, accelerating the discovery process through molecular simulation and analysis. Future studies could explore these technological features and further advance the discourse on sustainable business model innovation from a technology affordance perspective.

6. Conclusion

Our study provides an account of how space technology plays an enabling role in the implementation of sustainable business model innovations. Specifically, our findings show that firms can leverage the affordances of space technology to overcome the transaction obstacles that hinder their contribution to sustainability goals. By adopting a technology affordance perspective, our research explores a previously unexplored area at the intersection of sustainable business model innovation and space technology. In doing so, our study makes several contributions to the literature on sustainable business model innovation, technology affordances, and the emerging New Space Economy. In addition, our study offers practical implications for managers, entrepreneurs, and policymakers by providing a novel framework for sustainable business model innovation in the New Space Economy.

CRediT authorship contribution statement

Jacopo Manotti: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Silvia Sanasi:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Antonio Ghezzi:** Writing – original draft, Supervision, Project administration, Funding acquisition.

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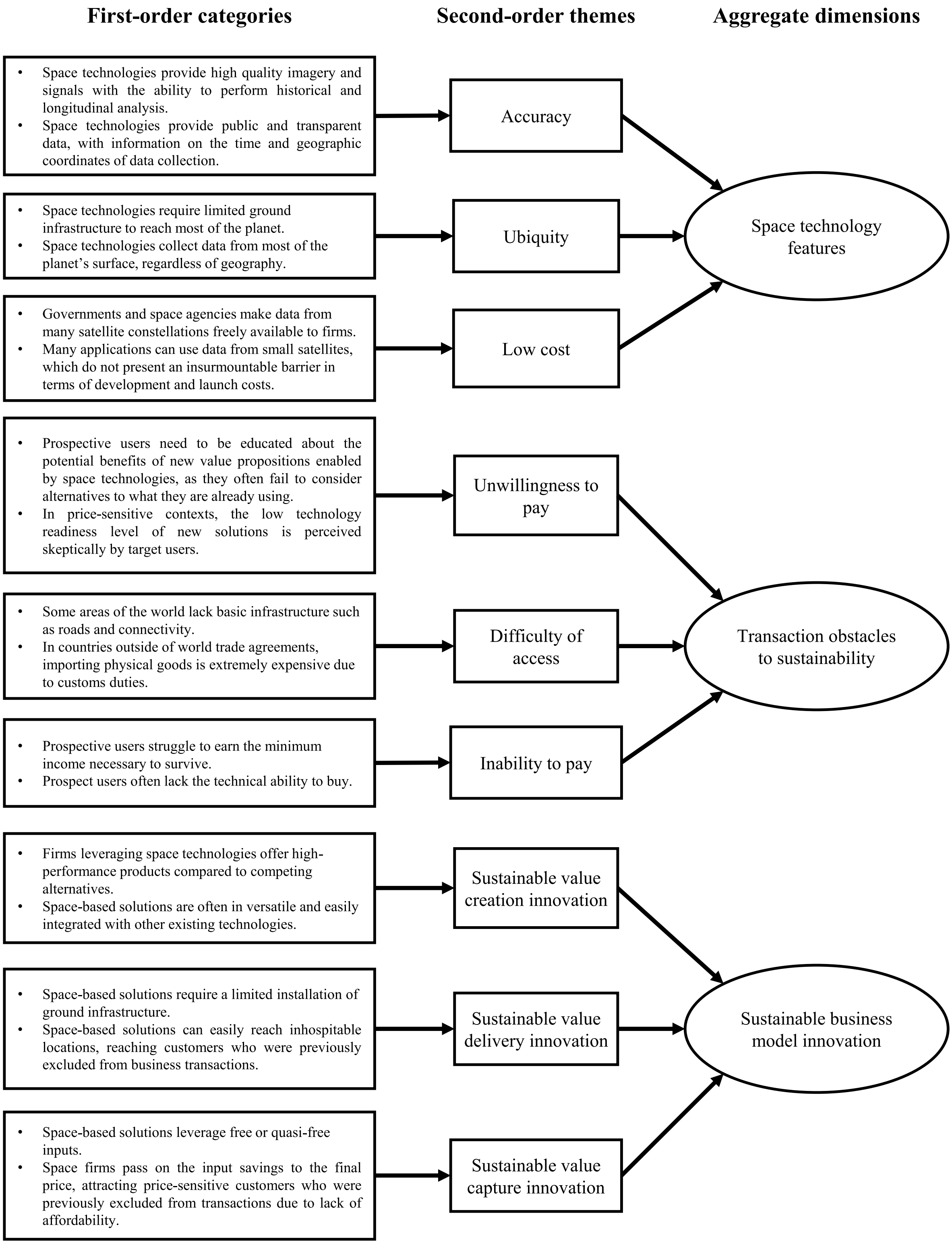
APPENDIX A

Case Selection.

Entrepreneurial venture (pseudonym)	Foundation year	# Employees	HQ location	Total financing raised (million euro)	Target customer industry
Alpha	2017	31	Israel	8.34	Agrifood
Beta	2018	20	United States	8.24	Construction
Gamma	2018	8	Argentina	0.06	Legal Compliance
Delta	2011	85	Canada	55.51	Insurance, Real Estate
Epsilon	2016	22	United States	0.21	Weather Forecasting
Zeta	2018	8	Luxembourg	0.5	Agrifood
Eta	2010	24	Sweden	4.49	Food
Theta	2018	36	United States	20.47	Forestry
Iota	2011	24	Belgium	1.50	Telecommunications
Kappa	2016	38	United States	24.12	Logistics, Transportation
Lambda	2016	6	Switzerland	0.06	Energy, Utilities

APPENDIX B

Data structure.



APPENDIX C

Representative supporting data for second-order themes.

Second-order themes	First-order codes and representative quotations
Aggregate Dimension: SPACE TECHNOLOGY FEATURES	
Accuracy	Space technologies provide high quality imagery and signals, with the ability to perform historical and longitudinal analysis. "*High resolution over large areas not possible with other terrestrial technologies.*" (Gamma) "*Whereas with satellites like Sentinel, even though we've only been around for a year or two, our economic data sets go back to 2003, when this latest class of imagery started being acquired. So when we develop a model that's validated on today's data, it gives us a huge amount of value and kind of time indexing and developing trends over time.*" (Beta) Space technologies provide public and transparent data, with information about the time and geographic coordinates of the data collection. "*Possibility to choose the exact latitude and longitude of the data I want to acquire, with very high resolution*" (Epsilon) "*So you can cover more ground, and look at larger areas, and you can also look at the whole world.*" (Delta)
Ubiquity	Space technologies require only limited ground infrastructure to reach most of the planet. "*With satellites you can reach rural areas where there is no terrestrial infrastructure.*" (Iota) "*Satellite images are ubiquitous, it's possible to reach remote places where there is no chance to install weather sensors and IoT devices of developed countries.*" (Zeta) Space technologies collect data from most of the planet's surface, regardless of geography. "*With satellites we are able to directly reach an entire continent.*" (Iota) "*We have been global from day one, because satellite data provide access to all the regions of the world.*" (Lambda)
Low cost	Governments and space agencies make data from many satellite constellations freely available to businesses. "*For satellites images you just have the processing cost, because the public constellation provides images for free.*" (Alpha) "*We have historically primarily used open-source satellite data from the European Space Agency.*" (Beta) Many applications can use data from small satellites, which do not present an insurmountable barrier in terms of development and launch costs. "*Small satellites are low cost, and a solution to make things more affordable for developing countries.*" (Iota) "*Small size of satellites enables them to be built, launched, and maintained with massive savings, and to pass them to the end user.*" (Kappa)
Aggregate Dimension: TRANSACTION OBSTACLES TO SUSTAINABILITY	
Unwillingness to pay	Prospective users need to be educated about the potential benefits of new value propositions enabled by space technologies, and often do not consider alternatives to what they already use. *"I think the most important barrier is financial and digital literacy, literacy in general, because when you understand that how digital and financial tools support your resilience, you start growing your business.*" (Eta) *"Our major challenge I think is the market, is getting to those people, and showing the value to them in a simple way for them to use that*." (Alpha) In price-sensitive contexts, the low technology readiness of new solutions is perceived skeptically by target users. *"The other let's say barrier will be the technology readiness. You know that there are some things that have to be done manually or that we have to bring in other partners to get a result that they can plug in and make and create value for them.*" (Delta) *"Also, in the most developed areas of Africa, the diffusion of basic technology is not so high. So that providing them something new that is technology-based is not so easy."* (Alpha)
Difficult of access	Some areas of the world lack basic infrastructure, such as roads and connectivity networks. *"Developing countries do not have other option than satellites to connect to the internet, because in rural areas there is no terrestrial infrastructure.*" (Theta) *"Without enough population density, deploying terrestrial infrastructure is not a viable alternative for business.*" (Iota) In countries outside of world trade agreements, importing physical goods is extremely expensive due to customs duties. "*The second problem concerns importing goods, because the custom duties in African countries are extremely high.*" (Iota) "*Most of the companies operating in emerging countries have local partnerships. This is the main solution to corruption, often making entering the country very difficult, especially due to the customs duties at the different borders.*" (Zeta)
Inability to pay	Prospects struggle to earn a minimum income for daily survival. "*Our prospective customers in Africa live for one month on the amount of money we spend in one day. That's a completely different scale, that makes most of the technology impossible to afford for them.*" (Zeta) "*You can see most of the population outdoors during the day there. They are not really working as we intend; they are waiting for any opportunity to make the money to survive today.*" (Iota) Prospects are often not in the technical condition to buy. "*Most of the people do not have a bank account. They are not in the condition to either establish a traditional commercial relationship with a foreign company. However, they all have mobile phone plans, that's what we leveraged.*" (Eta) "*Technologies requiring complementary infrastructure are difficult to sell in some emerging countries. Simply because there is not such infrastructure. The more your solution is standalone, the better it is.*" (Kappa)
Aggregate Dimension: SUSTAINABLE BUSINESS MODEL INNOVATION	
Sustainable value creation innovation	Firms leveraging space technologies offer high-performance products compared to competitors' alternatives. "*By using satellite images, we can deliver maps of large fields for farmers. For such kind of application, there is no need to use drones, which are more expensive.*" (Gamma) "*Monitoring large and dynamic phenomena requires a helicopter view. You cannot use drones or ground data to get information about informal settlements. The only alternative is the satellite.*" (Alpha) Space-based solutions are often versatile and easy to integrate with other existing technologies. "*We send them our space-based alerts by SMS. Integrating our service with an already diffused technology within the population made our life easier.*" (Eta) "*Some public organizations installed ground sensors over the years to monitor the general conditions of the environment. Using latitude and longitude as identifiers, we can easily merge space data with other sources of data, providing richer insights and information.*" (Delta)
Sustainable value delivery innovation	Space-based solutions require limited installation of ground infrastructure, which drives business scalability. *"We just manufacture a small antenna to install where the receiver would like to have the signal. No other infrastructure. This makes us go very fast in spreading the solution.*" (Iota) "*Our company works with just satellite images. We collect data remotely from the public constellation, then we deliver digital analytics to customers worldwide, without any need for physical infrastructure installation.*" (Lambda)

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(*continued*)

Second-order themes	First-order codes and representative quotations
	Space-based solutions can easily reach inhospitable locations, reaching customers who were previously excluded from doing business. "*In some areas of the globe, maritime logistics deal with the issue of piracy. Therefore, insurance is very important, but insurance companies do not want to take the risk if they cannot model it. Using satellite is the only alternative to include these kinds of situations in the insurance business, providing worldwide measurements.*" (Kappa) "*Africa is full of remote villages with few inhabitants, while well-developed countries keep large infrastructure in rural areas. The issue is similar: going there with human presence it's costly and dangerous. Space allows remote access to many of those areas.*" (Iota)
Sustainable value capture innovation	Space-based solutions leverage free or quasi-free inputs. "*Because we don't have to deploy personnel on the ground, that's obviously a lot cheaper … It's just a processing cost, given the use of public data.*" (Delta) "*Our solutions are largely based on data gathered for free from Copernicus. No acquisition cost beyond the need to have people able to read and process such data.*" (Lambda) Space companies pass on input savings, attracting price-sensitive customers who previously did not do business due to lack of affordability. *"We've kept our company exceptionally lean, which allows us to pass all of the savings to our customers thus reducing the final price.*" (Epsilon) *"The small size of the satellites would enable them to be built, launched, and maintained less expensively than other constellations, thus allowing Kappa to pass massive savings along to the end user, and making global satellite connectivity affordable like never before."* (Kappa)

Data availability

The data that has been used is confidential.

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