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Abstract:

As organizations seek to address urgent environmental challenges, emerging technologies (ET) such as artificial intelligence, IoT, and blockchain offer new opportunities to enhance sustainability. Two key phenomena—network effects and ontological reversal—are increasingly shaping how organizations leverage ET in business model design to drive environmental impact. This study examines how digital organizations can incorporate mechanisms enabled by ET affordances, particularly those linked to ontological reversal, to harness network effects for sustainability. In doing so, we respond to calls for research on how ET not only support but actively transform physical reality, fostering collaborative environmental value creation in digital ecosystems. Through an in-depth literature review and an analysis of industry cases, we develop both a typology of network effects and a theoretical model for sustainable business model design. Our typology identifies three value-creation mechanisms of network effects—participation, data mediation, and learning moderation—which are integrated with three manifestations of ontological reversal—data infusion, virtualization, and dematerialization—that clarify how organizations generate environmental value with ET. Our theoretical model provides a structured approach for organizations to strategically align digital business models with sustainability goals.

Keywords: Digital Sustainability, Green Information Systems, Ontological Reversal, Network Effects, Digital Platforms, Ecosystems.

[Department statements, if appropriate, will be added by the editors. Teaching cases and panel reports will have a statement, which is also added by the editors.]

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1 Introduction

Environmental sustainability is a pressing issue as climate change threatens ecosystems and societies. There are various threats that need to be addressed urgently. These include the reduction in biodiversity, rising sea levels that affect communities living in coastal areas, a decrease in agricultural production that leads to food scarcity, pollutants that harm our well-being and access to clean water, and the instability of resources and trade that affects businesses' operations. Numerous organizations, including the Intergovernmental Panel on Climate Change (IPCC, 2023) and the European Commission, through the framework of the European Green Deal (European Commission, 2023), are emphasizing the urgent need for climate action.

The private sector has an important role to play in reducing environmental degradation and creating sustainable socio-economic systems (Watson et al., 2008; Seidel et al., 2017; Frey and Sabbatino, 2018) as "much of the unsustainable activity that occurs in the world can be traced to organizations" (Etzion, 2018). The move towards sustainable business models is both a strategic shift to ensure the long-term value-creation in the organization (Stubbs & Cocklin, 2008), also creating an opportunity to attract and retain talent with environmental concerns (Guerci et al., 2016; Wagner, 2011), and an increasing demand from customers, representing a source of customer satisfaction (Luo & Bhattacharya, 2006).

Given the impending force of digital technologies in business and the need for environmental action, aligning digital and sustainable action is momentous, and it provides a valuable opportunity for incumbents to capture and create value, while saving the costs that would originate from undergoing two separate transformations (Böttcher et al., 2024). In the words of Houlin Zhao, Secretary-General of the International Telecommunications Union states that:

> *"Today, we are faced with not one but two deep transformations. The first one, driven by emerging technologies such as artificial intelligence, blockchain, the Internet of Things, 5G and many others, is changing how governments, businesses and individuals will act in this new century. As for the second transformation, climate change, it disrupts ecosystems, jeopardizing biodiversity, food and water security and the future of life on our planet. […] The question for us is whether humanity can turn this digital revolution into climate action and, most importantly, whether we can do it before it is too late."* (International Telecommunications Union [ITU], 2019, p. V)

Emerging technologies (ET) are widely available, driving profound changes in industries and society and providing multiple opportunities to accelerate environmental action (Melville, 2010; Dwivedi et al., 2022). In recent years, ET such as artificial intelligence (AI), robotics, internet of things (IoT), big data analytics cloud-based platforms, and blockchain have provided opportunities for established firms to innovate and transform their businesses, aligning environmental and economical sustainability (Böttcher et al., 2024; Kotlarsky et al., 2023). For example, L'Oréal develops sustainable cosmetic products with AI (IBM, 2025), Unilever uses AI in its supply chains (Unilever, 2023), and Persofoni AI's SaaS solution helps companies with their carbon accounting, sustainability compliance, and decarbonization strategies (Persefoni AI, 2024). ET have also led to a wave of lucrative digital start-ups that address climate issues (Böttcher et al., 2024). For instance, the start-up Ecobee uses IoT and AI to provide smart heating solutions that save energy (Ecobee, 2024).

ET are at the same time part of the sustainability problem and solution (Dwivedi et al., 2022). While digital solutions consume hefty amounts of electricity and result in large amounts of electronic waste (e.g., Dwivedi et al., 2022), many have praised these ventures as partial solutions to address environmental degradation, support organizational sustainability objectives, and drive the circular economy (e.g., Böttcher et al., 2024; Hanelt et al., 2017; Kamble et al., 2023; Rosa et al., 2020; ITU, 2019).

ET, and the digital business models and ecosystem interactions they enable, have some unique properties, such as malleability, openness, convergence of technologies (Nambisan et al. 2017), that result in affordances: opportunities for action that arise directly from a technology's inherent properties and design, and that shape how users can interact with and leverage the technology to create value (Majchrzak and Markus 2012). These affordances have the potential to enable organizations to better achieve their sustainability goals and reach objectives that were previously unattainable, in part because they power network effects, which are self-reinforcing dynamics where value increases exponentially as more participants join and contribute to the ecosystem. These network effects create cascading impacts:

increased participation generates more data, which enables better optimization, which attracts more users, creating a virtuous cycle of environmental value creation. Additionally, ET create entirely new affordances that were not possible without these technologies. Using the same example of Ecobee's smart heating solutions, prior to the widespread of AI and IoT technologies, the traditional electricity grids could not dynamically reshape demand in real-time; they relied heavily on human intervention and scheduled predictions.

Two distinct phenomena appear from ET affordances that organizations must incorporate into their logic when designing a business model for sustainability—namely, network effects and the ontological reversal. While network effects are particularly prominent in digital platforms (e.g., Gregory et al., 2021, Karhu et al. 2024) they are not exclusive to the digital domain or platform architectures; however, certain digital affordances—such as ubiquity, generativity, re-programmability (Yoo et al., 2010; Nambisan et al., 2017; Watson et al. 2008)—amplify and accelerate them across various organizational forms. These network effects, which can manifest as virtuous cycles of growth, may be direct (stemming from interactions within the same group of participants, e.g., consumers) or indirect (arising from interactions between different groups, such as providers and consumers). By operating through feedback loops, network effects intensify externalities, which can be either positive or negative. Novel digital affordances of ET are also fundamentally reshaping the relationship between the physical and digital realms. They have enabled them not only to respond to physical reality, but also to actively create and shape it—a mechanism termed ontological reversal (Baskerville et al., 2020; Kotlarsky et al., 2023). The ontological reversal refers to the shifting primacy between digital and physical realms, where digital representations increasingly shape, mediate, and even precede physical realities in business operations and value creation.

In this article, we respond to the calls from Baskerville et al. (2020) and Kotlarsky et al. (2023) to investigate how ET-enabled digital organizations shape physical reality and co-create environmental value with stakeholders. The research question we explore in this article is: *How can digital organizations incorporate mechanisms—derived from affordances of emerging technologies and reflecting the logic of ontological reversal—into the design of their business models to leverage network effects and enhance sustainability?* According to Schaltegger et al. (2016), "a business model for sustainability helps describing, analyzing, managing, and communicating (i) a company's sustainable value proposition to its customers, and all other stakeholders, (ii) how it creates and delivers this value, (iii) and how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organizational boundaries" (p6). This definition goes beyond the widely accepted one proposed by Teece (2010): "A business model articulates the logic and provides data and other evidence that demonstrates how a business creates and delivers value to customers" (p. 173). It extends the concept by focusing on value not just for customers, but for all stakeholders and the environment, by explicitly incorporating natural, social, and economic capital.

Our study contributes to the existing literature by providing a novel theoretical model that advances research beyond existing frameworks in three critical ways. First, while Teece's (2010) business model framework focuses on firm-level customer value and Schaltegger et al.'s (2016) extends this to stakeholder value, our model reveals how network effects and ontological reversal create systemic environmental value that scales exponentially across digital ecosystems. Second, whereas Green IS frameworks (Watson et al., 2010; Melville, 2010; Gholami et al., 2016) treat IT as an enabler of sustainable practices through optimization and efficiency, we demonstrate how emerging technologies fundamentally reshape physical reality as active agents that autonomously generate environmental benefits. Third, our framework uniquely theorizes how data-mediation and AI-driven learning transform network effects (Afuah, 2013; Iansiti, 2021; Gregory et al., 2021; Clough and Wu, 2022) from simple scaling mechanisms into active forces that, combined with ontological reversal (Baskerville et al., 2020; Kotlarsky et al., 2023), create self-reinforcing cycles of environmental value—a phenomenon not addressed in existing sustainable business model frameworks.

Section 2 reviews relevant literature on environmental sustainability in IS research, network effects and sustainability, and the ontological reversal. Section 3 presents our research approach, explaining our conceptual-empirical methodology and case selection criteria. Section 4 provides a typology of network effects, clarifying data and data-driven learning's role in environmental value creation. Section 5 discusses how the ontological reversal and network effects can aid in designing organizations that create environmental value. Section 6 summarizes the theoretical and practical implications, and section 7 presents conclusions and directions for future research.

2 Theoretical Background

2.1 Environmental Sustainability in IS Research

Literature on digital sustainability highlights three levels of effects based on the impact of digital technologies on sustainability (Köhler & Erdmann, 2004; Dedrick, 2010; Asadi et al., 2017):

- First-order effects stem directly from the hardware lifecycle that makes up digital technologies, such as those emerging from sourcing and using materials to produce digital equipment and the electricity they consume.
- Second-order effects are those of digital technologies on organizational systems, like logistics and manufacturing, which increase their productivity. In this case, ET influence how organizations' systems create, deliver, and capture environmental value—an organization's business model. An example involves using ET to enable product traceability and enhance customers' environmental consciousness.
- Third-order effects refer to the dynamic and long-term consequences that influence economic (e.g., the reduction of relative resource intensity; Berkhout and Hertin, 2001) and social systems, subsequently shaping the outcomes of first and second-order effects.

While these three orders of effects provide a useful taxonomy, our model primarily addresses second- and third-order effects, with implications across all levels. We focus on how network effects and ontological reversal mechanisms operate at the intersection of organizational systems (second order) and broader socio-economic transformations (third order). Although individual organizations implement these mechanisms, network effects, by definition, transcend firm boundaries to create ecosystem-wide and societal impacts. For instance, network-enabled data sharing may begin as an organizational initiative (second order) but scale to reshape entire industries (third order). Similarly, AI-powered optimization can transform not just individual business models but entire systems of production and consumption. Thus, our model operates at both firm and ecosystem levels simultaneously, recognizing that in networked digital environments, these levels are increasingly intertwined and mutually constitutive.

So far extant research has been categorized into two overlapping streams: Green Information Technology (Green IT) and Green Information Systems (Green IS). Green Information Technology (Green IT; e.g., Murugesan, 2008; Dedrick, 2010) studies first-order effects, while the field of Green Information Systems (Green IS; e.g., Watson et al., 2010; Melville, 2010; Dedrick, 2010; Wang et al., 2015; Gholami et al., 2016; Dwivedi et al., 2022) focuses on investigating the use of digital technologies to achieve environmental sustainability goals, i.e., second-order effects. Green IS extends its focus beyond the sustainability of IT infrastructure to encompass the sustainability of value-creating activities (i.e., the organizational business model). Lastly, examining third-order effects requires a long-term view and interdisciplinary analyses of socio-technical systems beyond the domain of any single discipline. Studies on the sustainable development of co-evolving technological systems and society are often found outside traditional information systems outlets, particularly in fields such as transition research (e.g., Lawhon and Murphy, 2012; Geels, 2019).

Research on the environmental sustainability of digital solutions offers some examples of studies of third-order effects, although the theoretical contributions to this space are still in the early stages. For instance, Jha et al. (2016), Leong et al. (2016) and Dixit et al. (2020) study the impact of digital solutions in communities in India and China. Jha et al. (2016) describe the case of eKutis, a social platform from the state of Odisha in India that aims to alleviate small farmers' poverty. The article identifies five phases in the development of the platform and five critical elements (e.g., technology, communities, intermediaries, institutions, and partners) that make a sustainable and scalable ecosystem. Leong et al. (2016) study the development of two rural Chinese communities as e-commerce via Taobao took root in them and provide recommendations to empower rural development with information and communication technologies. Last, Dixit et al. (2020) study how ICT platforms and renewable energy technologies can enable forest protection and renewable energy production in the Himalayan villages of India.

Other recent papers take different views on digital solutions as enablers of environmental and social action. For example, Ketter et al. (2023) investigate smart, sustainable mobility solutions, and underscore the role of IS in transforming transportation systems, which can lead to significant long-term environmental benefits through systemic change in urban mobility. Konietzko et al. (2019) discuss how online platforms could enable the circular economy as marketplaces, product-service systems, and innovation hubs and provide directions for practitioners. Schoormann et al. (2023) provide a systematic literature review of research at the intersection of AI and sustainability to understand how AI is currently used to advance sustainability goals and identify research gaps and future directions. Mancha et al. (2022) conceptualize the use of multi-sided platforms as nonprofit entities, analyze challenges, provide recommendations for their management, and explore the competitive landscape of ride-share companies in a city in the US where a nonprofit platform competes with for-profits like Uber.

While this extensive body of Green IS research has established important foundations, it primarily treats digital technologies as tools for optimization rather than as active agents of environmental change. Missing from this literature is an understanding of how digital technologies can autonomously create and scale environmental value through network dynamics—a gap that our study addresses.

2.2 Network Effects in Digital Business Models

Digital organizations are becoming increasingly dominant in many industry verticals. Leading global organizations, such as Google, Amazon, Alibaba, Netflix, Uber, Airbnb, and GitHub, base their success on leveraging network effects to innovate and create a competitive advantage (Schrage, 2016). Network effects emerge when the value of a product, service or system increases as the number of active users rises (de Reuver et al., 2018; Katz and Shapiro, 1985). Network effects can be direct (same-side), where value comes from users in the same group, or indirect (cross-side), where value is driven by users from another group (de Reuver et al., 2018).

Network effects have been extensively studied in digital platform research, with scholars identifying various types and mechanisms through which value is created and amplified (Eisenmann et al., 2006; McIntyre & Srinivasan, 2017). Network effects can occur in traditional markets such as financial exchanges, the adoption of technical standards like electrical plugs, and credit card acceptance. However, digital platforms often increase the visibility and scalability of these effects. Digital platforms inherently enable rapid scaling, facilitate seamless interactions among diverse user groups, and foster environments conducive to complementary innovations and dynamic ecosystems.

The platform ecosystem literature distinguishes between three main categories of digital organizations that exhibit different network effect dynamics.

- Digital technology platforms are purely technical IT artifacts representing modular and extensible codebases that third parties can extend with complementary modules (de Reuver et al., 2018; Tiwana et al., 2010). These platforms serve to develop multiple products and solutions through open innovation, generating direct network effects as more participants contribute data and complementary modules.
- Multi-sided platforms represent business models enabling direct interactions between two or more distinct user groups, where participants retain control over the terms of interaction (Hagiu & Wright, 2015). These platforms facilitate value exchange through marketplaces or innovation hubs, exhibiting both direct network effects within user groups and indirect effects across different sides.
- Platform ecosystems feature a central entity that orchestrates the ecosystem by providing a platform and setting rules for complementary offerings (Jacobides et al., 2018; Kapoor & Agarwal, 2017). Participants co-create value through innovative complements, generating complex patterns of direct and indirect network effects as the ecosystem grows.

Each platform type creates distinct patterns of positive and negative externalities that impact environmental sustainability, while also offering unique opportunities for designing network effects that actively promote sustainability outcomes. While these categories provide analytical clarity, they are not mutually exclusive—many successful platforms exhibit characteristics of multiple types or evolve from one type to another over time. For instance, a technology platform may develop marketplace features (becoming multi-sided) and eventually establish ecosystem governance (becoming a platform ecosystem). This fluidity is particularly relevant for sustainability initiatives, as organizations can strategically combine different network effect mechanisms to maximize environmental value creation across their evolutionary journey.

Building on affordance theory (Gibson, 1979; Majchrzak & Markus, 2012), we recognize that emerging technologies do not deterministically produce outcomes but rather offer possibilities for action that organizations must recognize and actualize. These affordances—such as real-time data collection through

IoT, pattern recognition through AI, and immutable record-keeping through blockchain—become particularly powerful when combined with network effects. The affordance perspective helps explain why similar technologies can produce vastly different sustainability outcomes across organizations: the value emerges from the interplay between technological capabilities, organizational choices, and network dynamics.

In this paper, we study the role of network effects on sustainability. Building on Afuah (2013), we posit that positive environmental impact is generated when environmental value is created and/or captured. We, thus, refer to a digital organizations' business model as environmentally sustainable when it captures economic value to maintain its operations and fulfill its fiduciary responsibilities while it acts to minimize its negative externalities on the environment.

Network effects in digital business models generate both positive and negative externalities that impact environmental sustainability. While positive externalities create value and encourage adoption, negative externalities can prevent participants from joining (Easley and Kleinberg, 2010). In environmentally sustainable digital business models, participant activities are directed at limiting the negative impact of business practices on society and the environment (e.g., limiting negative externalities) and in some cases even at creating a positive cycle of company and community development (i.e., positive externalities) (Porter and Kramer 2011). For example, the efficient use of resources (electricity and other inputs of production) and the acquisition of renewable or recycled materials directly decrease the environmental footprint, thus, reducing negative externalities. A second example is the elimination of waste by collecting post-consumer products to make other items. Alternatively, organizations can lead initiatives to create positive externalities by funding or carrying out environmental initiatives. An example is "1% for the planet" – a global environmental initiative in which participant members adhere to invest at least one percent of their annual revenue to environmental causes.

As the influence of network effects increases, potentially leading to significant negative externalities (e.g., increased CO_2 emissions due to higher power consumption), it is important that network-effects-based digital organizations grow responsibly. In addition, business models designed for exponential growth can also create positive externalities with a greater environmental impact. The ontological reversal also plays an important role as emerging technologies amplify their impact beyond merely optimizing physical systems (Baskerville et al., 2020; Kotlarsky et al., 2023). For example, digital twins allow organizations to model, predict, and optimize real-world physical processes, directly shaping material efficiency, resource allocation, and emissions reduction. Similarly, AI-driven automation and predictive analytics enable energy grids to self-regulate, reducing waste and enhancing sustainability efforts.

Research on network effects has so far focused on investigating the way the size of a network contributes to creating value, studying how increases in the size of one user group leads to increases in the size of that same user group or another user group (e.g., Katz and Shapiro, 1985; Parker et al., 2017; Rochet and Tirole, 2003). Recent theorizing, however, has challenged this key assumption and concluded that size is not the only determinant of value generation (Afuah, 2013; Clough and Wu, 2022; Haftor et al., 2021; Gregory, et al. 2021). Next to size, data and the learning from data-generated insights are also characteristics that contribute to value creation and capture with network effects (Clough and Wu, 2022; Haftor et al., 2021; Gregory, et al. 2021). Through ontological reversal, these data-driven insights not only refine digital organizations' ecosystems but also shape real-world sustainability outcomes—such as optimizing logistics to reduce carbon footprints or enabling precision agriculture to minimize water usage. This shift transforms digital business models from passive data processors into active agents of environmental change.

Given the relevance of data, which serves as the foundation of digital business models to drive innovation and sustainability initiatives (Kotlarsky et al., 2023; Krasikov and Legner 2023), and following the calls by Gregory et al. (2021) and Clough and Wu (2022) to investigate the effect of data-driven learning as a strategic resource that enhances value in digital organizations, in this paper we examine the effect of data-driven learning in the context of direct and indirect network effects in ET-driven business models. In line with Clough and Wu (2022) and opposed to Gregory et al. (2021), we do not consider data network effects as a distinctive type of network effects, but we see data as a variable that mediates or moderates value generation with network effects, thus creating new variations of direct and indirect network effects. By integrating ontological reversal into this analysis, we underscore how digital organizations are no longer merely intermediaries but active participants in shaping sustainable physical realities.

Our theoretical model also complements and extends other sustainability-focused digital business model theories. Circular platform models (e.g., Konietzko et al., 2019) focus on enabling circular economy principles through digital platforms but primarily address resource flows rather than the underlying mechanisms that create environmental value. Digital servitization frameworks (e.g., Kohtamäki et al., 2019) explain the shift from products to services but don't account for how network effects amplify sustainability outcomes. Value co-creation in ecosystems (Vargo & Lusch, 2016; Aarikka-Stenroos & Ritala, 2017) provides insights into collaborative value generation but lacks specific mechanisms for environmental value creation through digital technologies. Our model synthesizes these perspectives by integrating their insights while addressing their limitations. We incorporate circular platforms' focus on resource flows, servitization's emphasis on business model transformation, and value co-creation's collaborative dynamics, but extend them by revealing how network effects (participation, data-mediated, learning-moderated) and ontological reversal interact to create environmental value. Specifically, our model shows that these mechanisms don't just optimize existing sustainability efforts: they create new forms of value where digital systems autonomously generate environmental benefits that grow exponentially through network dynamics, scaling far beyond what individual organizations or even ecosystems could achieve independently.

Despite recent advances in understanding network effects, existing research has two key limitations. First, it largely focuses on economic value creation, with limited attention to environmental outcomes. Second, it treats network effects as byproducts of platform growth rather than as designable mechanisms for sustainability. Our model addresses both gaps by theorizing how specific network effect mechanisms can be purposefully designed to generate environmental value.

2.3 The Digital-Physical Ontological Reversal

The development and ubiquity of ET goes beyond impacting social structures, work tasks, and business processes, and is altering the relationship between physical and digital realities. Most organizations operate under the premise that digital technologies are developed to serve the needs and mirror the physical world—solutions are created to respond to physical challenges and opportunities (Baskerville et al., 2020). For example, companies use predictive analytics and IoT to optimize physical supply chain processes; health providers rely on electronic health care record management systems and wearable devices to enhance patient care; and retailers use digital marketing tools to generate customer insights and targeted advertising, which improves inventory management and the physical flow of goods and services. However, digital technologies are creating and shaping physical reality and not merely responding to it—what is termed ontological reversal (Baskerville et al., 2020; Kotlarsky et al., 2023). Under this perspective, digital artifacts such as algorithms, data analytics, and digital business models can be created to shape the physical environment, social interactions, and economic activities, driving the impact organizations have on the natural environment. In other words, the ontological reversal of physical and digital means that digital solutions cannot just be seen as tools for enhanced physical sustainability outcomes, but as entities that actively shape the physical world and recreate social norms. There are multiple examples of how ET can shape the physical reality:

- redefining the way products are designed, developed, used, and recovered to create the basis for circular business models,
- creating new conceptualizations of physical systems through digital twins where sustainability is not an outcome of the system, but built into the system by design, and materials with digital manifestations that enable their traceability, thereby offering novel models of circular recycling,
- improving operations through algorithms that prioritize sustainability and that result in new operational frameworks to which physical systems can be adapted,
- creating novel digital experiences that transform consumption,
- shaping decisions and behaviors to create default expectations about sustainable options, and
- forming platform ecosystems that create novel digital exchanges for services, transportation, and hospitality and that go beyond optimizing physical exchanges and that redefine socio-economic interactions and urban environments.

Extant literature identifies three broad manifestations of the ontological reversal: data infusion, virtualization, and dematerialization (e.g., Baskerville et al., 2020; Lehrer et al., 2018; Overby, 2008). Organizations embrace ETs insofar as they enable these manifestations and fundamentally transform their products, services, and operations (Baskerville et al., 2020). Data infusion—the embedding of analytics and data into innovative products and processes—enriches offerings and enables better decision-making across physical operations by creating tight data feedback loops between intelligence generation and operational execution. For example, Lehrer et al. (2018), in their exploratory, multisite case study across four industries, described the transformation of service offerings with big data analytics to deliver individualized value. Using event recognition, predictive analytics, and data visualization, firms enhance customer experiences and transition from reactive to proactive service models. Virtualization involves creating digital representations or environments to augment or replace hardware or physical processes. For example, Overby (2008) describes how once-physical processes, like shopping, are now conducted in virtual setting using digital technologies. In another study, Bose and Luo (2011) argue that process virtualization enables organizations to optimize resource allocation and utilization, reduce energy consumption, and contribute to green IT initiative. Finally, dematerialization refers to replacing physical elements with digital ones. In a theoretical study, Baskerville et al. (2020) discuss how the non-physical aspects of processes have primacy over the physical ones, or have fully replaced them, such as computer-aided designs that replace any physical design and precede the manufacture of the physical products, such as a car.

While the ontological reversal concept opens new theoretical possibilities, its application to sustainability remains underdeveloped. Current work identifies the phenomenon but provides limited guidance on how organizations can harness it for environmental benefit. Our study bridges this gap by connecting specific manifestations of ontological reversal to concrete mechanisms of environmental value creation.

3 Research Approach

This study employs a conceptual-empirical approach, developing theoretical insights through systematic integration of academic literature and empirical demonstrations from practice. Our model development followed an iterative process of theory building and empirical grounding, consistent with approaches for developing novel theoretical frameworks in information systems (Gregor, 2006; Weber, 2012). For the selection of empirical examples, we employed purposive sampling guided by three criteria: (1) diversity of industries to ensure broad applicability of our framework, (2) organizations recognized as leaders in implementing emerging technologies for sustainability, and (3) publicly documented cases with sufficient detail to illustrate our theoretical mechanisms. We specifically sought examples from early-stage implementations of AI and other emerging technologies, as leading organizations often pioneer approaches that later become industry standards, serving as innovation champions and models for their fields (Rogers, 2003).

Our conceptual model emerged through an abductive process, moving iteratively between theoretical concepts from the literature and patterns observed in practice (Dubois & Gadde, 2002; Timmermans & Tavory, 2012). This approach, which combines deductive and inductive reasoning, is particularly suited for theory development when existing frameworks incompletely explain emerging phenomena (Mantere & Ketokivi, 2013). We first identified key theoretical constructs (network effects, ontological reversal) from IS literature and then examined how these manifest in sustainability contexts through our empirical examples. This systematic combining approach (Dubois & Gadde, 2002) allowed us to develop our novel typology that distinguishes between participation, data-mediated, and learning-moderated network effects: categories that extend beyond traditional direct/indirect classifications to capture how data and AI transform value creation mechanisms in sustainable business models. These categories were both theoretically grounded in existing network effects literature and empirically observable in our sustainability-focused cases.

The validity of our model rests on logical coherence and empirical grounding rather than statistical generalization. By selecting exemplar cases that represent different manifestations of our theoretical mechanisms, we demonstrate the model's applicability across diverse contexts while acknowledging that future empirical research is needed to test its boundary conditions. To that end, we aim to conduct a follow-up empirical study designed to validate and further refine the model in broader and potentially more generalizable settings.

4 A Typology of Network Effects for Value Creation in ET-Driven Organizations

Our study contributes to the ongoing dialogue on how digital organizations leverage data to create value (Clough and Wu, 2022; Gregory et al., 2021). Specifically, we identify and theorize three distinct network effect mechanisms that shape digital business models and drive environmental value creation. These mechanisms manifest as either direct network effects, where the same type of participant is both the source and recipient of the value, or indirect (cross-side) network effects, where value is created by one type of participant and received by another.

- Participation: The increase in the number of participants creates additional value for new participants. As more users join, the interactions facilitated by the digital organization increase, leading to higher engagement and network benefits. For instance, in the context of a smart city, an increase in urban mobility and transportation companies on one side (Side A) creates incentives for public health services (Side B) to join. The digital organization acts as the central facilitator, enabling the interactions and ensuring that increased participation leads to joint environmental value creation, such as lower emissions, reduced waste, and, overall, improved urban sustainability.
- Data Delivery: Contributing data (e.g., CO_2 emissions, recycled share, material design parameters) within a network orchestrated by a digital organization—whether from digital-physical technologies (e.g., IoT products such as smart meters) or purely digital technologies that shape physical reality (e.g., digital twins simulating machine tests digitally, thus saving energy and reducing waste)—creates opportunities by making this information accessible to participants, enabling collaborative contributions toward environmental sustainability. For instance, 'Too Good to Go', which connects restaurants and supermarkets with users to minimize food waste by selling surplus food at reduced prices to individuals, collects data on the type of food being rescued as well as quantity and quality of the surplus food being offered. By aggregating and analyzing this data, the organization helps businesses optimize inventory management and minimize food waste, improving both economic and environmental value.
- Insights from Data-Driven Learning: Digital organizations can continuously extract insights from data-driven learning, dynamically generating additional value for participants (e.g., personalized assessments, AI-driven recommendations, product/service innovation). As an example of this mechanism, Google leverages extensive data from maps and other open sources, combined with AI-driven analytics, to power its Sunroof Project—an initiative providing individuals and businesses with personalized evaluations on the viability and benefits of installing solar panels. Through this approach, Google actively contributes to sustainability by enabling informed decisions about renewable energy adoption.

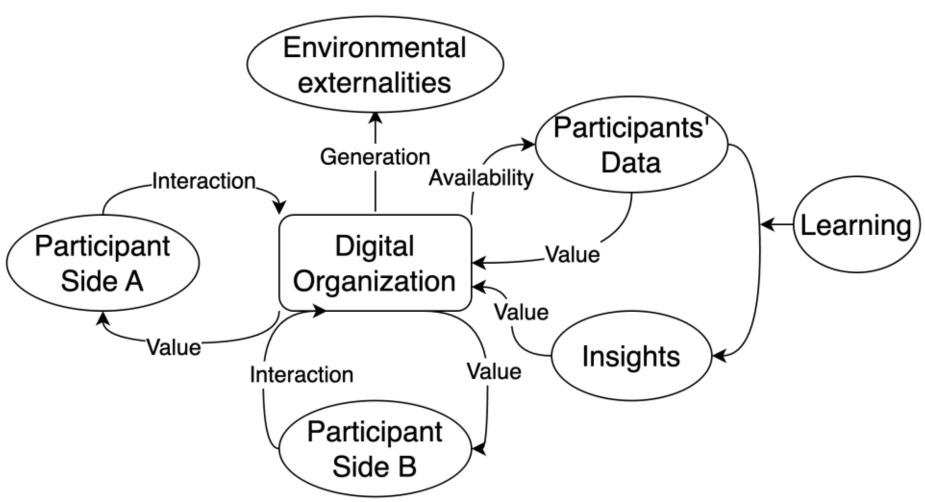

Figure 1. Graphical Overview of the Three Value Creation Mechanisms of Direct and Indirect Network Effects.

Digital organizations strategically design their business models to harness network effects, ensuring that as their ecosystem grows, sustainability benefits scale as well. An organization can conceive its participation in a network with other organizations to divert value to environmental sustainability. Based on the three mechanisms mentioned above, we identify three categories of network effects—depending on how value is created—and present a novel classification of network effects that drive environmental value.

First, participation network effects create increasing value as more participants join the network. As the number of users grows, so does the network's ability to drive sustainable outcomes—e.g., through shared access to resources, collaborative innovation, or collective environmental impact. Second, data-mediated network effects emerge when participants contribute data that is aggregated and shared among participants. These effects create both value within the same participant group or across different groups—sustainability-related data such as carbon emissions tracking generates environmental externalities through optimizations of the sustainability efforts of the participants. Third, learning-moderated network effects occur when the network processes participant-contributed data using automated technologies (e.g., machine learning, or predictive analytics). These insights create additional value for the contributors of data as well as other ecosystem participants. By continuously refining sustainability models—such as AI-driven energy optimization, predictive waste management, or circular economy simulations—learning-moderated network effects amplify the environmental and economic benefits of digital business models.

To illustrate how these three categories of network effects manifest in practice, we present prominent examples from leading organizations that demonstrate each mechanism. We selected these examples based on their clear illustration of the specific network effect type, their documented sustainability impact, and their recognition as industry leaders in digital sustainability initiatives. For each category, we examine both direct network effects (where value is generated and captured within the same participant group) and indirect network effects (where value flows between different participant groups). These cases not only support our typology but also reveal how organizations can strategically design their business models to leverage specific network effect mechanisms for environmental value creation. By analyzing how companies like Tesla, Octopus Energy, and Vinted operationalize these effects, we provide concrete evidence of how our theoretical categories map onto practical sustainability outcomes.

4.1 Participation Network Effects – Direct and Indirect

Participation network effects emerge from the interaction of participants in a digital organization's ecosystem. These effects can increase value within the same group of participants (i.e., direct network effects) or across different groups (i.e., indirect network effects). The contribution of the participants can range from mere presence (expanding the network) to active value exchange, such as providing services or solutions that enhance the ecosystem. Figures 2 and 3 illustrate the direct and indirect variants of participation network effects. These two types of network effects have been extensively studied in prior research (e.g., Hagiu and Wright, 2015; de Reuver et al., 2018) and are fundamental to the success of digital business models that scale through network-driven value creation.

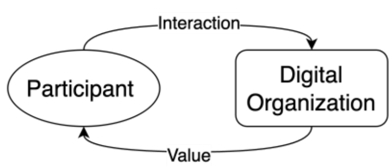

Figure 2. Direct Participation Network Effect

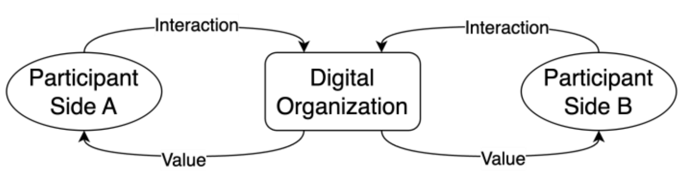

Figure 3. Indirect Participation Network Effect

As the number of participants in a digital organization's ecosystem grows, their contributions enhance the overall value of the network, making participation more attractive to new users and reinforcing adoption. As participation scales exponentially, digital business models can strategically align these network effects with environmental value-creation activities. In direct participation value creation, digital organizations leverage direct participation network effects by designing products, services and/or solutions that improve as user adoption grows. In indirect participation value creation, digital organizations operate multi-sided business models (e.g., marketplaces) designing incentives to balance supply and demand and ensuring both sides benefit from growth. For instance, the marketplace Vinted (https://www.vinted.com), which allows users to buy and sell second-hand clothing, is a peer-to-peer fashion marketplace with indirect participation network effects. Increased participation on each side (i.e., buyers and sellers) incentivizes more participants and opportunities to transact, and proportionally increases the environmental value generated, as more used clothes are sold through the marketplace, more used clothes are diverted from landfills, and fewer new items are purchased. Thus, participation network effects in digital business models can serve as powerful mechanisms to drive both economic growth and environmental sustainability.

4.2 Data-Mediated Network Effects – Direct and Indirect

Data-mediated network effects emerge when participants in a digital organization's ecosystem contribute data, which the organization then aggregates and shares across the network. Figures 4 and 5 represent how participant data availability mediates value creation directly and indirectly.

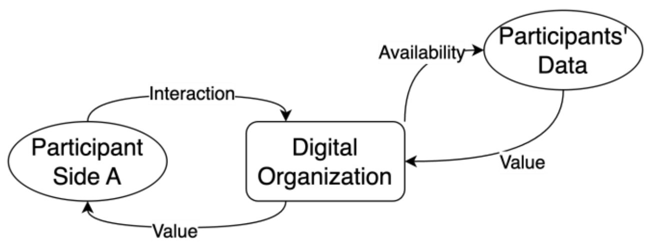

Figure 4. Direct Data-Mediated Network Effect

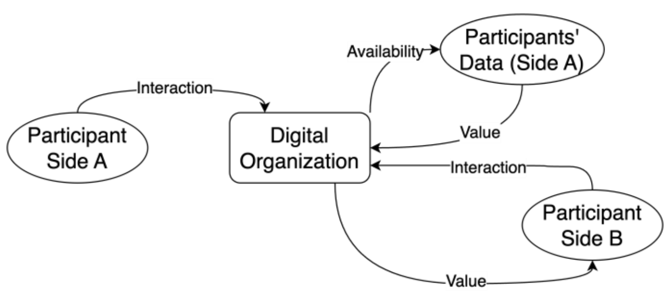

Figure 5. Indirect Data-Mediated Network Effect

Direct data-mediated network effects occur when data contributed by participants in one group directly enhances value for participants within the same group. For instance, Tesla drivers collectively contribute real-time driving data (traffic, charging status), which improves navigation and efficiency for all Tesla drivers. In this example, the data itself creates value, but the digital organization (Tesla) does not alter the dynamics of the network effects, i.e. Tesla does not engage in active learning or moderation of the interactions. At the same time, Tesla's navigation also creates indirect network effects, e.g., sharing the aggregated data with charging station operators, who can optimize the placement of the chargers as well the traffic flows. Both examples also reflect the reversed ontology of digital technologies, as Tesla digitally simulates real-world energy efficiency and charging scenarios instead of conducting physical tests. Direct and indirect data-mediated network effects further enhance the attractiveness of the digital organization's ecosystem to new users, amplifying its positive externalities and ameliorating the impact of negative externalities (e.g., reducing CO_2 emissions based on optimized routes).

4.3 Learning-Moderated Network Effects – Direct and Indirect

Learning-moderated network effects occur when digital organization's use AI-driven insights extracted from participant data to dynamically adjust and enhance interactions within their ecosystems. Unlike simple data mediation, learning moderation actively reshapes the mechanisms and dynamics of value creation, benefiting participants directly within the same group (direct effects) or indirectly across different participant groups (indirect effects). Figures 6 and 7 show how the learning from participant data actively moderates the value created in these processes.

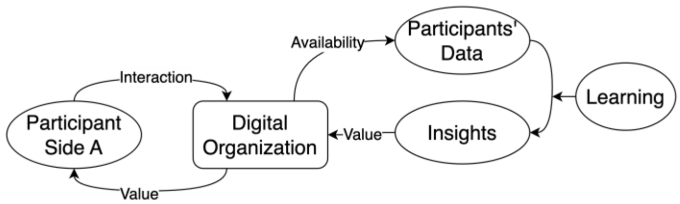

Figure 6. Direct Learning-Moderated Network Effects

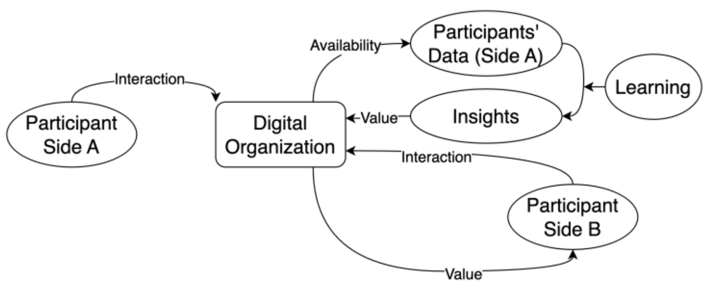

Figure 7. Indirect Learning-Moderated Network Effects

Direct learning-moderated effects emerge when AI-based learning directly creates value within the same group by dynamically improving interactions based on continuous feedback and insights. For instance, Octopus Energy (https://octopus.energy), a digital-first energy provider from the UK, operates a renewable energy supply network where households and energy providers contribute real-time energy consumption and generation data based on connected IoT devices, which is leveraged within its AI-powered platform Kraken. As more customers participate and share data, Kraken gets better at optimizing energy distribution and at dynamically adjusting pricing and consumption, thereby benefiting all customer in the network though lower bills (direct network effects). At the same time, Kraken also moderates how the energy market operates by predicting demand spikes and adjusting renewable energy sourcing (indirect network effects). Renewable energy producers, grid operators, and policy makers benefit indirectly as the insights from Kraken lead to collectively generating positive environmental network externalities, as more stable energy grids reduce reliance on fossil fuels, and a better integration of renewable resources into the overall energy mix.

Like with the examples of Tesla in the data-mediated network effects, the examples of Octopus Energy also reflect the reversed ontology of digital technologies as it is through patterns and future scenarios that AI-driven insights actively shape energy usage. Through digital simulations, Kraken AI dynamically influences real-world energy infrastructure, substantially enhancing environmental sustainability.

Table 1 below, provides an overview summarizing the most relevant characteristics and impacts of data-mediated and learning-moderated network effects.

Table 1. Overview of Data-Mediated and Learning-Moderated Network Effects: Key Characteristics and Outcomes

Dimension	Data-Mediated Network Effects	Learning-Moderated Network Effects
Role of Data	Participants contribute data that is then aggregated and delivered to participants	Participants contribute data that is processed and made available either through (a) learning based on insights from data analytics and/or (b) AI-based adaptive learning
Role of AI/Learning	None	(a) Learning via insights from data analytics (in some cases based on AI) and/or (b) automated continuous learning from data and actively reshaping network interactions based on AI
Degree of Value Creation	Incremental; value scales gradually based on data contributions	(a) Incremental; value scales gradually based on data contributions (b) Radical; value scales exponentially as AI optimizes the network interactions
Example of Direct Network Effect	Tesla vehicles collect and share real-time traffic, road condition, and charging data. As more vehicles provide data, Tesla (as the orchestrating organization) improves its navigation and charging systems for all Tesla drivers, enabling more efficient routes and energy savings	Kraken AI learns from data on consumer energy use and continuously adjusts and optimizes real-time energy pricing and energy usage for all Octopus customers, improving their collective impact on the environment
Example of Indirect Network Effect	Aggregated data from Tesla users can indirectly benefit other group of participants such as city planners and charging infrastructure providers, which indirectly helps in the planning of smart cities	Kraken AI dynamically moderates interactions between consumers and energy producers. Based on AI-driven predictions from consumers' data it can it help grid operators balance demand and energy supply

5 Ontological Reversal and Network Effects to Create Environmental Value

As digital organizations have evolved into more complex structures, understanding the network effects and dynamics has also become increasingly more intricate (Afuah, 2013; McIntyre and Srinivasan, 2017). This emphasizes the need for a new approach for accounting for the value creation potentials of digital organizations with network effects.

In the previous section, we provide a novel classification of network effects within groups and between groups that are mediated by the data collected or moderated by data-driven learning. These three categories of network effects describe how three different mechanisms of data—participation, data delivery, and insights from data-driven learning—lead to environmental value creation by either increasing positive environmental externalities (e.g., promoting sharing economy business models, such as product service systems (PSS), that contribute to circular economy) or by reducing/ameliorating negative environmental externalities (e.g., reducing the carbon footprint via improved efficiency of energy consumption). In conjunction with the three manifestations of the ontological reversal discussed—data infusion, virtualization, and dematerialization—network effects create powerful value creation (and destruction) dynamics to consider in the design of sustainable business models. Figure 8 below presents our theoretical model, which illustrates how network effects and the manifestations of the ontological reversal interact to form reinforcing feedback loops that shape environmental outcomes of digital organizations.

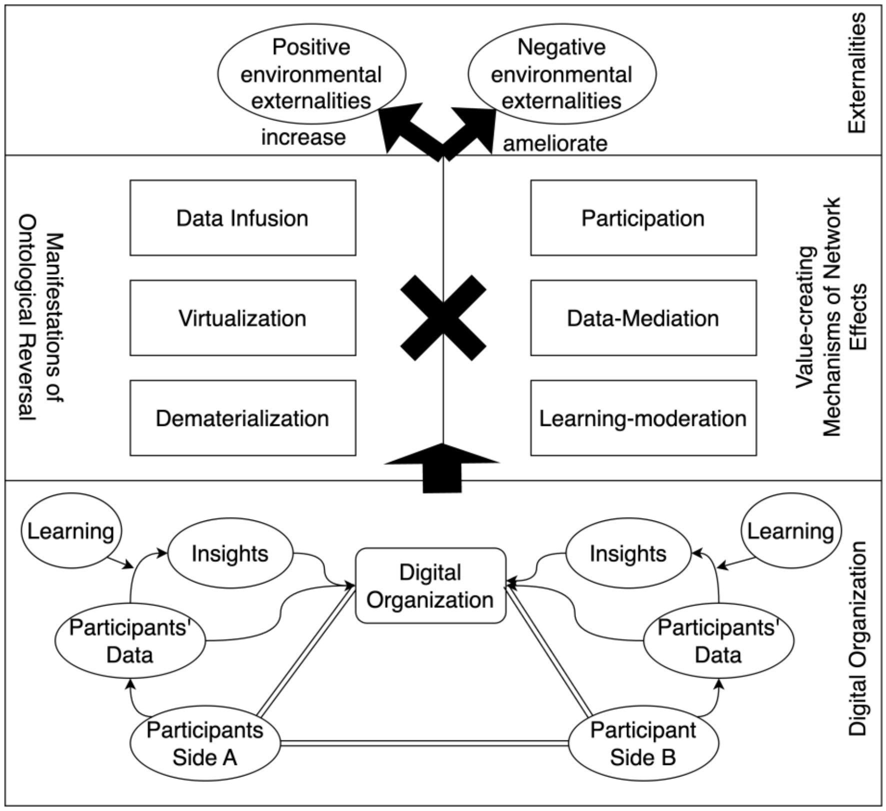

Figure 8. A Theoretical Model of Data Network Effects and Ontological Reversal in Sustainable Business Model Design

At the basic level of reinforcement, participation generates data that informs decision-making without directly driving action, such as using dashboards to visualize information or replacing physical documents with digital ones. Here, data plays a passive role with limited feedback and no automation, keeping decision-making reliant on human intervention and technology as static representations of the real world. In contrast, strong reinforcement forms a self-sustaining dynamic where participation, data-mediation, and learning continually reshape physical processes. Digital artifacts not only represent but also act upon their environment, learning and adapting over time. For example, a digital twin for electricity grid management uses real-time data from millions of users, predictive analytics to anticipate demand, and AI-driven automation to regulate energy distribution. This system optimizes power flow and learns from emerging patterns, making grid operations more autonomous and efficient. Over time, digital intelligence displaces manual control, effectively governing physical outcomes.

By integrating the ontological reversal manifestations into their business model, companies can create environmental value not only in theory but also through observable and actionable mechanisms. For example, dematerialization results in a measurable reduction in the use of physical resources by replacing material components with digital alternatives, such as paperless logistics systems−thereby minimizing energy consumption and lowering emissions. Virtualization reduces the need for physical infrastructure or prototypes through simulation-based tools such as digital twins or virtual environments that allow for real-time adjustment and testing without physical material input. Last, data infusion is operationalized when companies embed real-time data streams directly into their processes leading to more efficient use of resources and reduced environmental impact. For instance, in precision agriculture platforms where drones and soil sensors collect continuous environmental data, enabling automated adjustments to fertilizer application based on real-time nutrient levels. This minimizes chemical overuse, reduces runoff, and enhances both crop yield and environmental performance.

Thus, the ontological reversal can be measured and observed through indicators such as the *degree of automation* (e.g., autonomous decision-making by AI systems), the *replacement* of physical assets or processes *with digital equivalents* (e.g., virtual prototypes or remote diagnostics), and the extent to which *digital systems monitor and actively intervene in physical environments* (e.g., real-time adjustments in energy distribution or logistics).

As shown in Figure 8, these ontological reversal manifestations do not operate in isolation—they are often powered and amplified by underlying network effects. For example, learning network effects generate insights or real-time adaptations that promote sustainable actions. These effects are particularly impactful in cases of advanced data infusion or virtualization, where digital technologies not only inform but actively govern decision-making to reinforce environmental goals.

Table 2 shows examples of ontological manifestations across network effects. By embedding these interactions into their business model, companies can create, deliver, and capture environmental value more effectively and systematically.

Table 2. Examples of Ontological Manifestations Across Network Effects

Ontological Reversal Manifestation	**Participation Network Effect**	**Data-Mediated Network Effect**	**Learning Moderated Network Effect**
Data Infusion	A real-time citizen-scientist air quality monitoring platform.	Farmers using IoT sensors and satellite data contribute real-time environmental data (e.g., soil moisture, weather patterns, crop health) to a shared digital platform.	Smart grids adjusting energy distribution based on real-time usage patterns.
Virtualization	A peer-to-peer virtual energy marketplace where households simulate energy supply and demand, match excess solar energy with neighbors, and trade energy in real time without relying on centralized utilities.	A digital twin of an electricity grid aggregates real-time energy usage data from millions of participants and helps businesses and individuals make consumption decisions.	Simulated factory environments improving production efficiency, reducing waste.
Dematerialization	A virtual healthcare consultation platform, where presence of more patients attracts providers and increases value.	A mobility platform integrates transportation options, and it aggregates commuting patterns to inform transportation decisions.	AI optimizing paperless workflows based on usage patterns.

Our theoretical model presents a conceptualization that theorizes how organizations generate environmental value within digital ecosystems. This is based not only on the size of the network (i.e., number of participants) but also on data delivery and insights from data-driven learning. Organizations enable the collection of large volumes of data (Haftor et al., 2021; Gregory et al., 2021), which are then either provided directly to participants or analyzed through machine learning algorithms to derive additional insights. Data infusion, virtualization, and dematerialization further build on and promote network effects. These processes create value, which organizations can monetize or use for sustainability initiatives. The total environmental value generated for participants depends on both the scale of the organization (i.e., products and services offered by participants) and the externalities resulting from network effects within groups (i.e., direct) and between groups (i.e., indirect), mediated by the data collected or moderated by insights from data-driven learning.

Ontological reversal fundamentally reshapes digital organizations by positioning digital elements as active shapers of the physical world. Building on our earlier discussion of network effects—where mechanisms such as participation, data delivery, and data-driven insights enable digital organizations to create environmental value through either enhancing positive externalities or mitigating negative ones—this perspective extends the model further. Digital organizations are no longer seen as passive intermediaries; instead, their digital artifacts (like algorithms and data analytics) are now central to molding physical systems, influencing everything from production processes to consumer behavior and environmental outcomes.

While our proposed theoretical model explains environmental value creation through the interaction of network effects and the manifestations of ontological reversal, its practical application depends on several contextual conditions. Drawing on the empirical examples presented in Table 2, we posit that the effectiveness of each type of network effect is shaped by the way ontological reversal is manifested in practice:

- *Proposition 1: Participation effects are strongest when user density is high and contributions are visible or reciprocated, particularly in cases of dematerialization and data infusion that lower participation costs and increase user engagement.*
- *Proposition 2: Data-mediated effects gain traction when sensing and connectivity infrastructures are robust, especially under conditions of data infusion and virtualization, which enable continuous system responsiveness.*
- *Proposition 3: Learning-moderated effects are most impactful when systems act autonomously based on data feedback, a dynamic most evident in advanced manifestations of virtualization and data-driven dematerialization.*

This dual dynamic between network effects and ontological reversal has significant implications for the design of digital organizations. Digital elements must both inform and be informed by the physical realm, fostering an integrated approach that redefines sustainable practices. In essence, digital organizations now serve as pivotal agents in not only creating but also actively orchestrating environmental value, driving a continuous cycle of innovation that aligns business practices with sustainability imperatives.

6 Implications for Theory and Practice

Our study has multiple implications for theory and practice.

6.1 Implications for Theory

Our theoretical model provides three novel insights absent from prior frameworks. First, unlike Teece's (2010) customer-centric value creation or even Schaltegger et al.'s (2016) multi-stakeholder approach, we reveal how environmental value emerges from network dynamics rather than firm-level activities. Second, we move beyond Green IS's focus on IT as an enabler (Watson et al., 2010) to show how digital technologies become autonomous agents of environmental change through ontological reversal. Third, while existing models treat data as an input for decision-making, our typology of network effects demonstrates how data-mediation and learning-moderation create entirely new value creation mechanisms that continuously evolve without human intervention.

6.1.1 Environmental Sustainability in IS Research

Prior research in green IS has established that digital technologies can serve as enablers of environmentally sustainable practices (e.g., Melville 2010; Watson et al. 2010; Gholami et al. 2016). Most of these studies emphasize either the role of IT in optimizing energy consumption and resource use (i.e., first-order effects related to “green IT”) or in supporting broader organizational changes (i.e., second-order effects related to “green IS”) (Köhler & Erdmann, 2004; Dedrick, 2010; Asadi et al., 2017).

Our study contributes to the largely unexplored domain of third-order effects—systemic, long-term transformations in the structure and logic of socio-technical systems—by investigating two powerful but understudied phenomena: network effects and ontological reversal. We demonstrate how organizations can design sustainable business models around three key network effect mechanisms: participation, data-mediation, and learning-moderation. These mechanisms can be further amplified through manifestations of ontological reversal—namely, data infusion, virtualization, and dematerialization.

Specifically, we theorize how digital technologies, through the interaction of network effects and ontological reversal, can scale environmental value creation beyond individual firms to influence broader economic coordination, infrastructure design, and social practices.

While previous research acknowledges the potential of interorganizational systems, data sharing, and collaboration to promote green outcomes (e.g., Watson et al. 2008; Dedrick 2010), our study provides a novel typology of network effects that clarifies how digital organizations can either amplify positive environmental externalities or compound negative ones within their ecosystems. We show that designing business models for sustainability requires strategically orchestrating ecosystem-level interactions, where environmental value is generated collaboratively based on the three value-creating mechanisms and informed by design choices related to the manifestation of the ontological reversal—as potential amplifiers of the network effects.

6.1.2 Network Effects in Digital Business Models

In line with recent research that has challenged the key assumption that network size is the primary determinant of value (e.g., Afuah, 2013; Clough and Wu, 2022; Haftor et al., 2021; Gregory, et al. 2021), we extend this perspective by highlighting data-driven and AI-driven learning as pivotal levers that impact the sustainability outcomes of network effects.

Our paper responds both to Kotlarsky et al. (2023), who stress the importance of exploring the role of diverse actors in digital sustainability ecosystems, and to Schoormann et al. (2023), who emphasize that prior studies investigating the role of AI on sustainability impact often adopt a relatively narrow lens (e.g., focusing on isolated technologies or specific impacts) instead of addressing the broader, interconnected nature of ecosystems. By underscoring the relevance of learning-moderated network effects, our study demonstrates how AI can optimize sustainability outcomes at the ecosystem level through a continuous adaptation of the network interactions based on continuous learning, rather than merely at the organizational level. For example, the discussion of Octopus Energy illustrates how AI-driven automated adaptation in energy grids can jointly reduce costs and carbon emissions through continuous, real-time learning.

This broader, ecosystem-oriented perspective reveals that network effects in digital sustainability contexts are not solely driven by participant growth (i.e., traditional direct or indirect network effects). Rather, data and AI actively reshape how participants interact over time, enabling collective sustainability gains that surpass what any individual organization could achieve. Hence, by integrating insights on data-mediated and learning-moderated network effects into a broader sustainability model, our paper advances the literature on digital ecosystems and network effects, clarifying how continuous data sharing and AI-based adaptive learning and optimization can be harnessed to reinforce positive environmental externalities—and mitigate negative ones—across interconnected digital organizations.

6.1.3 The Digital-Physical Ontological Reversal

Our contribution to the discourse on the digital-physical ontological reversal is two-fold. First, we extend the conceptual scope of the digital-physical ontological reversal into the domain of digital sustainability. Whereas Baskerville et al. (2020) identify numerous challenges associated with digital technologies actively shaping physical reality—such as ethical concerns related to automation, privacy, and autonomy—our study shifts focus toward the environmental value-creation potential of this reversal. Specifically, we illustrate how a digital-first approach can amplify the impact of value-creation mechanisms of network effects. Drawing from Kotlarsky et al. (2023), we show how digital-first ET, such as digital twins and AI, proactively influence and enhance sustainability outcomes in the physical domain through simulations and data-driven analytics. They can either mitigate negative externalities—for example, through simulations that optimize resource management to reduce waste and CO2 emissions—or even amplify positive externalities, such as enhanced electrical grid efficiency and the integration of cleaner energy mixes.

Second, responding to Baskerville et al.'s (2020) call for frameworks of value creation grounded in ontological reversal, we present a novel theoretical model that links this ontological shift with the logic of network effects in digital sustainability. Our model identifies and theorizes three categories of network effects—participation-based, data-mediated, and learning-moderated mechanisms—as central drivers of environmental value that are in some cases further amplified by manifestations of ontological reversal, specifically through data infusion, virtualization, and dematerialization.

6.2 Implications for Practice

The contribution of our study to practice is two-fold. First, it highlights the importance of embracing a digital first mindset and balancing the digital-physical interconnectedness. Advancements with ET are motivating companies to embrace a digital-first mindset, unlocking new opportunities to substantially enhance their environmental outcomes. Organizations should assess how they can benefit from ET digitally *preceding* their physical products (e.g., virtualization that optimizes the design or performance through simulations with digital twins), *shaping* them (e.g., autonomous decision-making by AI systems) or *replacing* them (e.g., reducing waste implementing paperless processes). This assessment can help them strategically design their business models to optimize the integration of the digital and physical elements towards maximizing environmental value creation.

Second, our typology of network effects and our theoretical model provides a blueprint for organizations to design collaborative ecosystems based on three mechanisms—participation, data-mediation, and learning-moderation—and the three manifestations of the ontological reversal—data infusion, virtualization, and dematerialization—that delineate how organizations can create collective environmental value by increasing positive network externalities (e.g., promoting sharing economy business models, such as product service systems (PSS), that contribute to circular economy) or by reducing/ameliorating negative environmental externalities (e.g., reducing the carbon footprint via improved efficiency of energy consumption).

Based on our model we propose four actionable principles that companies can implement to design sustainable business models in interconnected ecosystems: (1) embed learning loops to ensure that machine learning supports automated, sustainability-oriented decision-making; (2) enable digital autonomy so systems can respond in real time (e.g., dynamic pricing in energy markets); (3) map ontological transitions to identify where physical-to-digital shifts or automation yield environmental gains; and (4) prioritize interoperable data ecosystems to ensure that participation produces reusable data, amplifying learning across stakeholders.

7 Conclusion and Future Research

Our study develops a theoretical model that explains how digital organizations leverage network effects and ontological reversal to generate environmental value at scale. By examining the intersection of these phenomena through emerging technologies, we provide both a novel typology and an actionable theoretical model for sustainable business model design. More specifically, we investigate the following research question: *How can digital organizations incorporate mechanisms—derived from affordances of emerging technologies and reflecting the logic of ontological reversal—into the design of their business models to leverage network effects and enhance sustainability?* In addressing this question, we respond to recent calls by Baskerville et al. (2020) and Kotlarsky et al. (2023) to investigate how ET not only respond to but actively shape physical reality, fostering collaborative environmental value creation with users and complementors in digital organization ecosystems. Our key findings identify:

Three distinct network effect mechanisms that drive environmental value in sustainable business models:

- Participation effects: Value increases as more participants join, creating environmental benefits through scale.
- Data-mediated effects: Aggregated participant data enables collective sustainability optimizations.
- Learning-moderated effects: AI-driven insights continuously reshape network interactions for environmental value.

Three manifestations of ontological reversal that amplify these network effects:

- Data infusion: Embedding real-time analytics into physical processes for resource optimization.
- Virtualization: Digital representations that eliminate physical prototyping and testing.
- Dematerialization: Replacing physical components with digital alternatives.

The synergistic interaction between network effects and ontological reversal creates reinforcing feedback loops, where digital artifacts not only represent but actively shape sustainable physical realities. This model fundamentally differs from established frameworks in the literature. Traditional business models (Teece, 2010) and even sustainable business models (Schaltegger et al., 2016) remain firm-centric, focusing on how individual organizations create value. Green IS frameworks (Watson et al., 2010; Melville, 2010) treat technology as a tool for optimization. In contrast, our model demonstrates how digital ecosystems generate environmental value through three mechanisms—participation, data-mediation, and learning-moderation—that operate at the network level and are amplified by ontological reversal. This represents a paradigm shift: from viewing sustainability as an organizational outcome to understanding it as an emergent property of digitally mediated network dynamics.

The evolving interplay between network effects and ontological reversal opens critical avenues for future research. Empirical studies should test our propositions across diverse industry contexts, examine the boundary conditions of different network effect types, and investigate potential negative consequences of digital-physical integration. As emerging technologies continue to advance, researchers must also explore how new capabilities—such as quantum computing or advanced robotics—might further transform sustainable business models. While our theoretical contribution is grounded in academic literature and industry examples, empirical validation remains necessary. Nevertheless, we provide a robust foundation for understanding how digital organizations can become pivotal agents of environmental value creation. As the climate crisis intensifies, the imperative to align technological innovation with sustainability has never been more urgent. Our model offers a pathway for organizations to harness the transformative power of network effects and ontological reversal for planetary benefit.

AI Disclosure

During the preparation of this work, the authors used ChatGPT to complement index-based searches of relevant literature, and ChatGPT, Copilot, and Claude for editorial purposes to correct syntax and grammar and improve the clarity of the text.

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