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Navigating digital-geopolitical disruptions: reconfiguring Global R&D, innovation networks, and value creation in multinational enterprises

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Introduction: The convergence of digital transformation and geopolitical fragmentation is fundamentally reshaping how multinational enterprises (MNEs) organize innovation, knowledge flows, and value creation across borders. While prior research has examined these forces independently, limited attention has been given to their combined effects. To address this gap, this conceptual paper develops the Digitally Enabled Fragmentation (DEF) framework to explain how MNEs navigate the paradox of increasing digital connectivity alongside growing geopolitical, regulatory, and institutional divisions.

Methods: Drawing on a structured thematic synthesis of literature across international business, innovation management, and strategic management, the study integrates theoretical insights from Internalization Theory, the Knowledge-Based View (KBV), and Dynamic Capabilities Theory to build a multi-level explanatory model.

Results: The proposed multi-level framework links macro-level digital and geopolitical disruptions, meso-level reconfiguration of innovation networks and global value chains, and micro-level organizational capabilities that enable adaptation, resilience, and sustained value creation. Additionally, six theoretical propositions are developed to guide future empirical research on innovation resilience, network reconfiguration, and strategic adaptation in MNEs.

Discussion: The paper advances theory by conceptualizing DEF as a distinct phenomenon defined by the simultaneous coexistence of integration and fragmentation in global innovation systems. By emphasizing firm-level adaptation mechanisms and R&D network reconfiguration under uncertainty, it extends existing perspectives on techno-nationalism, digital sovereignty, and decoupling. Ultimately, the DEF framework provides a foundation for understanding how firms balance openness, resilience, and strategic autonomy, offering a roadmap for future empirical investigation of digital-geopolitical disruptions.

KEYWORDS

digital transformation, dynamic capabilities, geopolitical fragmentation, global innovation, multinational enterprises

1 Introduction

The global innovation landscape is undergoing profound transformation as two powerful and intertwined forces, digital disruption and geopolitical fragmentation, reshape how multinational enterprises (MNEs) conduct research and development (R&D), coordinate global innovation networks, and capture value across borders (Vrontis et al., 2024; Zhou and Wang, 2025). The rapid diffusion of digital technologies such as artificial intelligence (AI) (Zhai et al., 2024), blockchain (Tripathi et al., 2023), cloud computing (Zhang, 2025), and the Internet of Things (IoT) (Sorri et al., 2022) has fundamentally altered how knowledge is created, codified, and shared. At the same time, intensifying geopolitical tensions, economic nationalism, and technological decoupling have challenged the very foundations of cross-border collaboration that underpinned globalization over the past three decades (Rane et al., 2024). The confluence of these forces represents a structural turning point in the global economy, requiring MNEs to rethink how they organize for innovation and competitive advantage.

Digital transformation offers MNEs new pathways for coordination and knowledge integration. Cloud-based systems, digital twins, AI-driven analytics, and virtual collaboration platforms have enabled geographically dispersed teams to innovate with unprecedented efficiency (Bongomin et al., 2025). Digitalization increases the modularity and scalability of innovation activities, allowing firms to leverage global knowledge ecosystems while reducing coordination costs. However, this digital promise is tempered by growing vulnerabilities (Appiah et al., 2025). As data becomes a strategic asset, governments have introduced restrictive data localization laws, cybersecurity regulations, and digital sovereignty policies (Jansen et al., 2023). These measures, often rooted in national security concerns, fragment global data flows and constrain digital collaboration across jurisdictions.

In parallel, the resurgence of geopolitical rivalry has fractured the international innovation order. The U. S.–China technology rivalry, the weaponization of trade policy, and the proliferation of regional technology blocs have all disrupted established global value chains (Luo and Van Assche, 2023; Zhang, 2024). Geopolitical tensions now permeate decisions on foreign direct investment, R&D location, and intellectual property governance. MNEs must navigate an increasingly complex landscape where access to markets, technologies, and talent is mediated by political considerations as much as by economic logic. The rise of techno-nationalism, where nations seek technological self-sufficiency and strategic autonomy, further challenges the notion of globally integrated innovation networks (Luo and Van Assche, 2023; Verbeke et al., 2025).

These dual disruptions, digital and geopolitical, are deeply intertwined. Digital technologies simultaneously serve as mechanisms of global integration and instruments of geopolitical control (Bednarski et al., 2023). They facilitate cross-border knowledge exchange, collaboration, and innovation while also increasing exposure to data restrictions, cybersecurity regulations, technological sanctions, and digital sovereignty initiatives. This paradox creates what we term Digitally Enabled Fragmentation (DEF), a condition in which digital technologies sustain global connectivity even as geopolitical and institutional divisions increasingly constrain cross-border innovation activities. Under conditions of DEF, multinational enterprises must continuously balance openness and control, efficiency and resilience, and global integration and strategic autonomy. Success therefore depends not only on technological capabilities but also on the ability to

reconfigure innovation architectures, governance mechanisms, and organizational capabilities in response to evolving digital and geopolitical pressures (Heikinheimo et al., 2025).

Existing theories of global strategy and innovation management provide valuable insights into how firms manage international knowledge flows, internalize capabilities, and balance exploration and exploitation (Zámborský et al., 2023). However, most were developed under conditions of relative geopolitical stability and open global markets. Internalization theory (Casson, 2015) explains why firms internalize cross-border activities to mitigate transaction costs. However, it does not fully account for the political risks and regulatory fragmentation of the digital era. The knowledge-based view (KBV) emphasizes the role of knowledge recombination and learning networks, yet it often assumes frictionless information flows (Hamilton and Philbin, 2020). Dynamic capabilities theory highlights firms' abilities to sense and respond to change, but it rarely addresses how digital and geopolitical contexts co-evolve to shape those capabilities (Alrub and Sánchez-Cañizares, 2025).

To address these gaps, we develop an integrative conceptual framework that theorizes the co-evolution of digital transformation and geopolitical fragmentation and their combined impact on MNE innovation strategies. The framework links macro-level forces (geopolitical and technological disruptions) to meso-level network structures (alliances, partnerships, and value chains) and micro-level firm responses (dynamic and digital capabilities). It explains how MNEs leverage digital technologies to maintain connectivity and knowledge flow in a fragmented global environment while adapting their innovation architectures for resilience and strategic autonomy.

To guide the development of this framework, the study is structured around the following research questions:

RQ1: How do digital transformation and geopolitical fragmentation jointly reshape the global innovation environment for multinational enterprises (MNEs)?

RQ2: How do these macro-level disruptions influence the structure and reconfiguration of global R&D and innovation networks?

RQ3: What firm-level capabilities enable MNEs to adapt and sustain innovation under conditions of digitally enabled fragmentation?

These research questions reflect a multi-level perspective that links macro-level disruptions, meso-level network dynamics, and micro-level firm capabilities, forming the basis of the proposed conceptual framework. Addressing these questions requires a theoretical perspective capable of simultaneously capturing technological change, geopolitical disruption, and organizational adaptation. The following contribution statement and conceptual positioning of DEF establish the theoretical foundations for the framework developed in this study.

The paper makes three contributions to the international business, innovation management, and global strategy literature. First, it introduces Digitally Enabled Fragmentation (DEF) as a novel conceptual lens for understanding how multinational enterprises navigate the simultaneous pressures of digital integration and geopolitical fragmentation. Second, it advances theory by integrating Internalization Theory, the Knowledge-Based View, and Dynamic Capabilities Theory into a unified framework that explains how firms adapt innovation

systems under conditions of digital–geopolitical disruption. Third, it develops a multi-level framework linking macro-level environmental forces, meso-level network reconfiguration, and micro-level organizational capabilities, and derives six propositions that provide a foundation for future empirical investigation.

Although the growing literature on digital transformation and geopolitical disruption has generated several related concepts, important gaps remain in explaining how multinational enterprises adapt their innovation systems under conditions of simultaneous digital integration and geopolitical fragmentation. Existing concepts such as digital fragmentation, digital sovereignty, techno-nationalism, decoupling, and geopolitical risk provide valuable insights into specific dimensions of this phenomenon. However, these perspectives often focus on technological systems, state policies, or environmental uncertainty in isolation.

Digitally Enabled Fragmentation (DEF) extends these perspectives by examining how multinational enterprises actively reconfigure innovation architectures, knowledge networks, and organizational capabilities in response to evolving digital–geopolitical pressures. Rather than viewing integration and fragmentation as opposing outcomes, DEF conceptualizes them as coexisting and mutually reinforcing processes that reshape global innovation systems. This perspective places firm-level adaptation at the centre of analysis while recognizing the influence of broader institutional and geopolitical dynamics.

The novelty of DEF lies in its multi-level perspective on innovation adaptation as shown in Table 1. By integrating insights from Internalization Theory, the Knowledge-Based View, and Dynamic Capabilities Theory, the framework explains how multinational enterprises respond to digital–geopolitical disruptions through the reconfiguration of innovation networks, governance structures, and organizational capabilities. This theoretical integration provides a foundation for understanding how firms balance resilience, openness, and strategic autonomy in increasingly fragmented global environments.

The remainder of the paper proceeds as follows. Section 2 reviews the literature on digital disruption, geopolitical fragmentation, and theoretical gaps in global strategy and innovation research. Section 3 develops the conceptual framework and presents a three-level model linking macro, meso, and micro dynamics. Section 4 formulates propositions that extend existing theories. Section 5 outlines managerial and policy implications, and Section 6 concludes by identifying future research directions for understanding global innovation in an era of disruptive change.

2 Research design and literature synthesis

2.1 Literature search and selection

This study adopts a conceptual theory-building approach based on a structured review and thematic synthesis of the literature. Relevant publications were identified through searches conducted in Scopus, Web of Science, and Google Scholar using combinations of the keywords “digital transformation,” “digital disruption,” “geopolitical fragmentation,” “techno-nationalism,” “multinational enterprises,” “global innovation networks,” “knowledge-based view,” “dynamic capabilities,” and “global R&D.” The search focused primarily on literature published between 2020 and 2025, while seminal earlier works were retained where necessary to establish theoretical foundations.

Studies were included if they addressed at least one of the following themes: digital transformation, geopolitical uncertainty, multinational enterprise strategy, innovation networks, knowledge integration, or organizational capabilities. Publications outside the domains of international business, innovation management, and strategic management were excluded. The

TABLE 1 Distinguishing DEF from related concepts.

Concept	Primary focus	Unit of analysis	Main limitation	How DEF extends existing perspectives
Digital fragmentation	Splintering of digital ecosystems and technological standards	Digital infrastructure and platforms	Limited attention to firm adaptation	Explains how firms reconfigure innovation systems under fragmentation
Digital sovereignty	National control over data, platforms, and digital infrastructure	State and regulatory systems	State-centred perspective	Integrates firm capabilities and innovation network responses
Techno-nationalism	Technology as an instrument of national competitiveness and security	State–industry relations	Focuses primarily on geopolitical competition	Examines organizational adaptation across multiple levels
Decoupling	Separation of economic and technological systems	Global value chains and trade relationships	Emphasizes disconnection processes	Recognizes simultaneous integration and fragmentation
Geopolitical risk	Political uncertainty affecting business activities	External business environment	Primarily descriptive	Identifies adaptation mechanisms and capability development
Digitally enabled fragmentation (DEF)	Coexistence of digital integration and geopolitical fragmentation	Macro, meso, and micro innovation systems	Integrative framework	Explains how firms sustain innovation and value creation under digital–geopolitical disruption

objective was not to provide an exhaustive systematic review but rather to identify and synthesize key theoretical insights relevant to understanding innovation under conditions of digital–geopolitical disruption.

2.2 Thematic analysis and framework development

Following article selection, a structured thematic analysis was undertaken to identify recurring concepts and relationships across the literature. An initial open coding process was used to identify key themes associated with digital transformation, geopolitical fragmentation, innovation networks, and organizational adaptation. Subsequently, axial coding was employed to explore relationships among these themes and to identify higher-order conceptual categories.

Through an iterative process of comparison, refinement, and theoretical integration, three interconnected analytical levels emerged: macro-level disruptions, meso-level innovation network structures, and micro-level organizational capabilities. These dimensions formed the basis for the development of the Digitally Enabled Fragmentation (DEF) framework. This approach enhanced conceptual rigor by ensuring that the framework was grounded in recurring patterns identified across multiple streams of literature while allowing for the integration of complementary theoretical perspectives.

3 Literature review

The dual forces of digital transformation and geopolitical fragmentation have generated significant yet under-theorized shifts in the global strategy and innovation landscape. This section synthesizes relevant scholarship across three major domains: (1) digital disruption and MNE innovation, (2) geopolitical fragmentation and techno-nationalism, and (3) theoretical gaps in explaining how these forces co-evolve.

3.1 Digital disruption and multinational enterprise innovation

The last two decades have witnessed a profound digital transformation that is reconfiguring global business models, innovation processes, and value creation logics. Digital technologies, including artificial intelligence (AI), blockchain, the Internet of Things (IoT), and cloud computing, have reshaped how MNEs generate, integrate, and appropriate knowledge across borders (Adamashvili et al., 2024). These technologies enable new forms of global connectivity, decentralized R&D, and real-time knowledge exchange (Pereira et al., 2022).

Digitalization enhances the modularity of innovation systems, allowing MNEs to unbundle and distribute R&D activities across geographically dispersed subsidiaries and external partners (Meyer et al., 2023). Modularity reduces coordination costs and allows firms to reconfigure innovation activities quickly in response to environmental change. Moreover, the codification and datafication of knowledge via digital tools improve the scalability and transferability of intellectual

assets (Foster, 2024). Through platform-based ecosystems and digital infrastructures, MNEs can leverage globally distributed resources while maintaining control over proprietary knowledge.

However, the digital transformation also introduces novel challenges. The same technologies that enable integration create new dependencies on digital infrastructure and expose firms to cybersecurity and privacy risks (Chotia et al., 2025). Digital interdependence increases systemic vulnerability: disruptions in one node of a network, whether due to a cyberattack, regulatory restriction, or technical breakdown, can cascade across the system (Palleti et al., 2021). Furthermore, the rise of data sovereignty and digital governance regimes constrains cross-border data flows, undermining the openness that global innovation has traditionally relied upon.

Emerging research indicates that MNEs are experimenting with hybrid R&D architectures that balance global integration and local adaptation (Jooss et al., 2021). Yet, much of the literature continues to treat digital transformation as a primarily technological process, overlooking its entanglement with political and institutional dynamics (Feliciano-Cestero et al., 2023; Plekhanov et al., 2023). To advance theoretical understanding, scholars must examine how digital affordances interact with geopolitical forces to reshape global innovation configurations.

3.2 Geopolitical fragmentation, techno-nationalism, and global innovation

Parallel to the digital revolution, the resurgence of geopolitical rivalry has disrupted the global innovation order (Luo and Van Assche, 2023). Geopolitical fragmentation refers to the breakdown of global integration resulting from political tensions, protectionist trade policies, and competing national interests (Campos et al., 2023). The rise of techno-nationalism, where states view technological capabilities as instruments of national power, has intensified competition for technological dominance (Godley et al., 2025).

Governments are increasingly using industrial policy, export controls, and investment screening to safeguard strategic technologies. For example, the U.S.–China technology rivalry has redefined global semiconductor and AI value chains. These interventions alter where and how MNEs conduct R&D, with whom they collaborate, and how they protect intellectual property (Schindler et al., 2024). As a result, firms face not only market-based risks but also geopolitical and regulatory uncertainties that directly shape innovation outcomes.

From a strategic management perspective, geopolitical fragmentation challenges the traditional logic of global integration. MNEs have long been seen as integrators of globally dispersed knowledge (Moura et al., 2025), yet the rise of national security restrictions and protectionist policies constrains such integration. Firms increasingly localize R&D, diversify supply chains, and restructure ownership patterns to comply with national interests (Belderbos et al., 2023). These responses signify a shift toward strategic regionalization, where MNEs manage multiple, semi-autonomous innovation networks tailored to distinct geopolitical environments.

Despite growing scholarly attention to deglobalization (Altman et al., 2024), existing studies tend to treat geopolitical tensions as exogenous shocks rather than as co-evolving systems intertwined with digital transformation. The result is a fragmented understanding of how political and technological changes jointly affect MNE innovation. A more integrated perspective is needed, one that captures how

geopolitical constraints interact with digital affordances to shape the architecture of global innovation.

3.3 Integrating theoretical perspectives: toward a multi-level understanding

While internalization theory, the knowledge-based view (KBV), and dynamic capabilities theory offer valuable insights into MNE innovation, each has limitations when applied to the dual-disruption context.

Internalization theory (Buckley, 2018) explains how firms internalize transactions to minimize market imperfections and protect proprietary knowledge. However, it assumes that political conditions are relatively stable and that firms can freely choose where to internalize or externalize R&D. In an era of techno-nationalism and data sovereignty, this assumption no longer holds. Geopolitical risks now dictate where firms can operate, whom they can partner with, and what technologies they can transfer (Bednarski et al., 2023). Internalization decisions thus reflect not only economic efficiency but also geopolitical calculus.

The knowledge-based view (Grant, 2015) conceptualizes the firm as an integrator of knowledge dispersed across boundaries. While this perspective explains how MNEs create and transfer knowledge, it often underestimates how institutional and political frictions disrupt these processes. In a fragmented global system, knowledge flows are filtered through regulatory firewalls, export controls, and divergent data standards (Cory and Dascoli, 2021). Therefore, the KBV must be reconceptualized to account for the *politicization of knowledge flows* and the strategic value of knowledge localization.

Dynamic capabilities theory (Land et al., 2022) provides a framework for understanding how firms sense, seize, and transform in response to change. Yet, it often treats environmental turbulence as exogenous and firm responses as internally driven. In the digital geopolitical context, however, turbulence arises from interactive feedback between technological and political systems. MNEs do not merely adapt to external shocks; they also shape the geopolitical environment through lobbying, standard-setting, and technology diplomacy (Shen et al., 2025). Thus, dynamic capabilities should be reinterpreted as geopolitically embedded capabilities that enable firms to manage uncertainty across political, institutional, and digital dimensions.

3.4 Research gap

The literature reveals substantial advances in understanding MNE innovation under either digital transformation or geopolitical disruption, but there is a limited synthesis of the two. Few studies theorize how digital affordances both amplify and mitigate the effects of geopolitical fragmentation. Likewise, there is limited research on how MNEs reconfigure global R&D networks and value creation logics to navigate this dual disruption.

More importantly, existing studies rarely examine how digital technologies simultaneously act as mechanisms of integration and sources of fragmentation. Consequently, the literature lacks a theoretical framework capable of explaining how multinational enterprises maintain innovation, knowledge flows, and value creation when digital connectivity and geopolitical fragmentation evolve concurrently.

This gap motivates the development of a new conceptual framework that integrates insights from global strategy, KBV, and dynamic

capabilities theory. The following section introduces the concept of digitally enabled fragmentation (DEF) and proposes a multi-level model linking macro-level disruptions, meso-level network structures, and micro-level strategic responses. This integrative perspective advances our understanding of how MNEs innovate and sustain competitiveness in an increasingly polarized global economy.

4 Conceptual framework: digitally enabled fragmentation

The convergence of digital transformation and geopolitical fragmentation presents multinational enterprises (MNEs) with a fundamentally new strategic context that existing theories only partially explain. While digital technologies increase connectivity, knowledge mobility, and innovation opportunities, geopolitical fragmentation simultaneously constrains cross-border collaboration through regulatory divergence, technological decoupling, and national security considerations (World Economic Forum, 2024). To explain how firms navigate these competing pressures, we introduce the concept of Digitally Enabled Fragmentation (DEF), defined as a condition in which digital technologies simultaneously sustain global connectivity and intensify exposure to geopolitical and institutional fragmentation. The DEF framework provides a multi-level analytical lens linking macro-level disruptions, meso-level network restructuring, and micro-level organizational capabilities. Through this framework, we theorize how MNEs reconfigure global innovation systems to balance resilience, openness, and strategic autonomy under conditions of digital-geopolitical disruption.

4.1 The logic of digitally enabled fragmentation

Digitally enabled fragmentation captures the paradoxical role of digitalization in the global economy. On one hand, digital technologies enhance connectivity, reduce transaction costs, and facilitate real-time collaboration across dispersed R&D units (Plekhanov et al., 2023). On the other hand, they increase exposure to systemic vulnerabilities such as cyber risk, digital surveillance, and data sovereignty conflicts (Mishra et al., 2022). As geopolitical tensions escalate, digital infrastructures themselves become arenas of competition and control.

In this environment, digital technologies serve dual purposes: they function as integration mechanisms enabling coordination across borders, and as fragmentation enablers when regulatory, political, or strategic interests restrict their use. MNEs, therefore, operate within digitally mediated ecosystems where innovation processes are global in architecture but increasingly local in governance. The DEF framework explains how MNEs use digital affordances, such as modular platforms, blockchain for transparency, and AI for risk analysis, to sustain innovation in fragmented ecosystems.

4.2 Multi-level framework: macro–Meso–Micro interactions

The DEF framework conceptualizes the interplay of global forces across three analytical levels and integrates three

complementary theoretical perspectives. Internalization Theory explains how firms adjust governance structures in response to changing transaction costs and regulatory constraints. The Knowledge-Based View (KBV) explains how firms create, integrate, and protect knowledge across dispersed innovation networks. Dynamic Capabilities Theory explains how firms sense environmental change, seize emerging opportunities, and reconfigure resources to sustain competitiveness. Together, these perspectives provide the theoretical foundation for understanding adaptation under conditions of digitally enabled fragmentation.

4.2.1 Macro level – global technological and geopolitical disruptions

At the macro level, two intertwined disruptions shape the context of MNE innovation: (1) digital transformation and (2) geopolitical reordering. Digital transformation refers to the adoption of advanced technologies that reshape industries, governance, and social systems (Plekhanov et al., 2023). Geopolitical reordering involves the strategic competition between states for technological dominance, manifesting through protectionist policies, sanctions, and technology embargoes (Li, 2025). Together, these forces create a hybrid environment of integration and fragmentation, where global digital infrastructures coexist with competing regional standards and institutional regimes.

From a theoretical perspective, this level extends internalization theory to include the influence of political transaction costs. These costs arise when MNEs must align operations with conflicting national regulations, negotiate data-sharing restrictions, or localize R&D to satisfy host-country security concerns (Röell et al., 2022). The macro environment defines the boundary conditions for firm behavior and determines the degree of strategic freedom available to MNEs.

4.2.2 Meso level – network reconfiguration and ecosystem adaptation

The meso level captures the structural and relational dimensions of innovation networks. It focuses on how MNEs orchestrate alliances, partnerships, and value chains to manage knowledge flows across borders. Under digitally enabled fragmentation, MNEs adopt selective coupling strategies, maintaining connections in cooperative domains while decoupling from high-risk or politically sensitive ones (Cieřlik and Zamojska, 2025). Network reconfiguration involves the dynamic reshaping of collaboration patterns, supply relationships, and technology-sharing arrangements to maintain continuity amid disruption (L. Li et al., 2025).

Digital technologies play a crucial enabling role. For instance, blockchain provides verifiable transaction records that reduce the need for centralized authority in trust-deficient contexts (Ghadi et al., 2024). Cloud-based R&D platforms enable asynchronous collaboration across time zones and regulatory jurisdictions (Holloway, 2024). AI-driven analytics allow firms to model geopolitical risk scenarios and adjust innovation portfolios accordingly (Jariwala, 2025). At this level, the KBV helps explain how firms manage distributed knowledge integration under institutional diversity, while dynamic capabilities theory elucidates how they reconfigure network architectures to preserve value creation.

4.2.3 Micro level – firm capabilities and strategic reconfiguration

At the micro level, firm-specific capabilities determine how effectively MNEs leverage digital affordances to navigate fragmented environments. Three types of capabilities are particularly salient:

- a *Digital capabilities*: The ability to deploy and integrate digital tools that enhance innovation agility, from cloud computing to digital twins and blockchain-enabled governance (Arkhipova and Bozzoli, 2018).
- b *Absorptive capacity*: The ability to identify, assimilate, and apply knowledge from external partners despite institutional and cultural barriers (Todorova and Durisin, 2007).
- c *Dynamic capabilities*: The higher-order ability to sense disruptions, seize emerging opportunities, and reconfigure resources accordingly (Teece, 2010).

These capabilities operate in tandem. Firms with strong digital and dynamic capabilities can design modular innovation architectures that maintain flexibility even when geopolitical shocks disrupt specific network nodes. They can redistribute R&D activities, transfer digital knowledge assets securely, and adjust governance mechanisms in real time. This adaptability transforms digital technologies from sources of vulnerability into instruments of strategic resilience. As shown in Figure 1, the Digitally Enabled Fragmentation (DEF) framework depicts how macro-level technological and geopolitical disruptions cascade through meso-level innovation networks and shape firm-level capabilities at the micro level.

Figure 1 illustrates the multi-level architecture of the Digitally Enabled Fragmentation (DEF) framework. The framework is organized around three interconnected levels. At the macro level, digital transformation and geopolitical fragmentation create the external conditions that shape firm behavior. These forces influence the configuration of innovation systems by altering regulatory environments, technology access, data governance requirements, and cross-border collaboration opportunities. At the meso level, multinational enterprises respond through the reconfiguration of innovation networks, strategic alliances, partnerships, and global value chains. Network adaptation serves as an intermediate mechanism through which macro-level disruptions influence organizational outcomes. At the micro level, firm-specific capabilities determine the effectiveness of adaptation. Digital capabilities, absorptive capacity, and dynamic capabilities enable firms to respond to changing conditions, maintain knowledge flows, and preserve innovation performance despite institutional constraints. The directional arrows in Figure 1 represent both cascading and feedback effects. Downward relationships indicate how macro-level disruptions influence network structures and firm capabilities. Upward feedback relationships illustrate how firm actions, including technology standard-setting, lobbying activities, and participation in international innovation ecosystems, can influence broader institutional and regulatory environments. The framework therefore conceptualizes digitally enabled fragmentation as a dynamic and co-evolutionary process rather than a one-way causal relationship.

4.3 Systemic interactions and feedback loops

The DEF framework emphasizes that interactions among the three levels are dynamic and recursive. Macro-level disruptions

trigger meso-level network adaptations, which in turn demand micro-level capability reconfiguration (Smith et al., 2019). Conversely, firm-level strategies feed back into the macro environment through lobbying, standard-setting, and technology diplomacy (Gorwa et al., 2024). For example, large platform firms influence international data standards and cybersecurity norms, shaping the geopolitical digital order itself.

This recursive logic suggests that the relationship between digitalization and geopolitics is not unidirectional but co-evolutionary. MNEs are not passive actors responding to external shocks; they are institutional entrepreneurs capable of influencing the rules of global innovation. Understanding these feedback dynamics is essential for building more adaptive theories of global strategy.

4.4 Theoretical contributions of the DEF framework

The DEF framework contributes to international business and innovation theory in four important ways. First, it introduces Digitally Enabled Fragmentation (DEF) as a distinct conceptual construct that explains the simultaneous coexistence of digital integration and geopolitical fragmentation. Unlike existing perspectives that focus primarily on fragmentation, decoupling, or technological sovereignty, DEF explains how firms actively maintain innovation and connectivity despite growing institutional divisions.

Second, the framework extends Internalization Theory by incorporating geopolitical and digital transaction costs into decisions concerning governance, location, and knowledge

protection. Third, it advances the Knowledge-Based View by recognizing that knowledge flows are increasingly shaped by political and regulatory constraints rather than solely by organizational design. Fourth, it enriches Dynamic Capabilities Theory by conceptualizing adaptation as a geopolitically embedded process in which firms continuously respond to interacting technological, institutional, and political pressures.

Collectively, these contributions provide a multi-level explanation of how multinational enterprises sustain innovation, resilience, and value creation in an environment characterized by both digital interdependence and geopolitical fragmentation. The framework also establishes a foundation for future empirical research through the development of theoretically grounded propositions presented in the following section.

5 Theoretical propositions

Building upon the Digitally Enabled Fragmentation (DEF) framework, this section develops a series of theoretical propositions that articulate how digital transformation and geopolitical fragmentation interact to shape the organization of global innovation. Each proposition integrates multiple theoretical perspectives, internalization theory, the knowledge-based view (KBV), and dynamic capabilities theory to capture the multi-level nature of these dynamics. Together, they provide a foundation for future empirical testing and further conceptual refinement. To enhance conceptual precision and facilitate future empirical investigation, each proposition is accompanied by illustrative boundary conditions and potential indicators that may be operationalized in subsequent quantitative or qualitative studies. These indicators are intended as examples rather than exhaustive measures and guide testing the relationships proposed within the Digitally Enabled Fragmentation (DEF) framework.

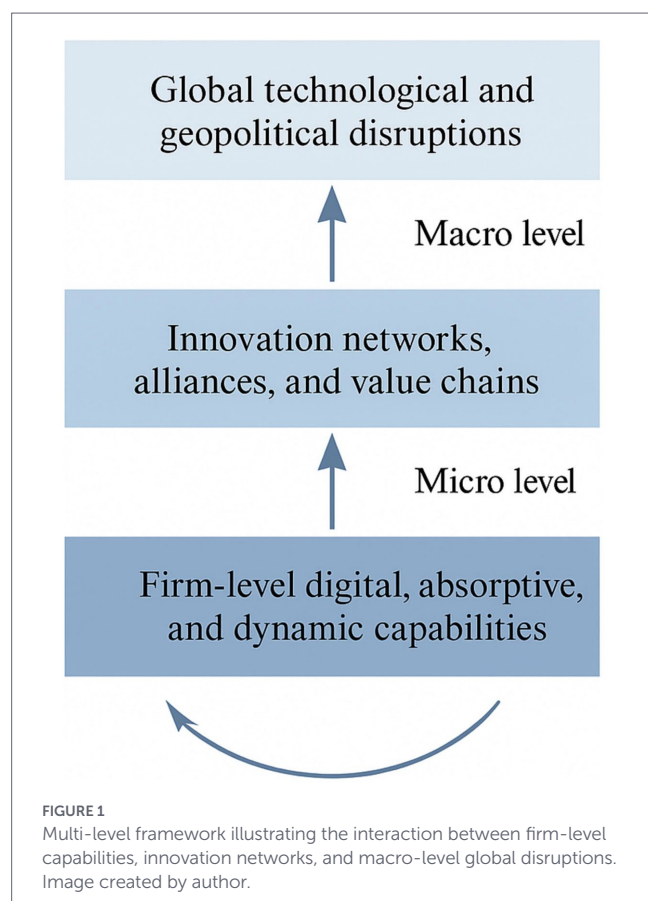
5.1 Digital modularity and resilience

Digital modularity (Swanson, 2024) refers to the decomposition of innovation systems into interdependent but loosely coupled components that can be independently developed and reassembled. Modular architectures enable MNEs to decentralize R&D, experiment across geographies, and adapt swiftly when environmental conditions shift (McDermott et al., 2013). Under geopolitical uncertainty, modularity acts as a structural hedge against systemic risk. If one unit or partner becomes constrained due to sanctions or policy barriers, others can continue operating with minimal disruption (Bednarski et al., 2023).

From an internalization theory perspective, digital modularity reduces transaction costs associated with coordination and knowledge transfer, allowing firms to manage complex innovation systems internally while maintaining flexibility. It also strengthens dynamic capabilities by facilitating the reconfiguration and redeployment of resources.

Proposition 1: Digital modularity enhances MNE resilience to geopolitical shocks by enabling distributed and reconfigurable innovation architectures.

Boundary conditions and illustrative indicators: The relationship is expected to be strongest in knowledge-intensive industries



characterized by high technological complexity and geographically dispersed innovation activities. Potential indicators include the degree of R&D modularization, the number of distributed innovation units, speed of innovation reconfiguration following disruption, and innovation continuity during geopolitical shocks.

5.2 Techno-nationalism and absorptive capacity

Techno-nationalism (Capri, 2024), the pursuit of technological autonomy and security by states, creates institutional barriers that limit cross-border collaboration and knowledge mobility. MNEs operating in such environments face declining access to global knowledge pools. Increasing pressure to localize R&D. However, firms with strong absorptive capacity—the ability to identify, assimilate, and apply external knowledge—can mitigate these challenges by developing locally embedded innovation units while maintaining global learning linkages through digital channels (Choksy et al., 2024).

In KBV terms, absorptive capacity represents a firm's ability to sustain learning under institutional diversity. The existence of techno-nationalist policies transforms absorptive capacity from a routine competence into a strategic capability essential for survival.

Proposition 2: Techno-nationalism increases local embeddedness but reduces cross-border absorptive capacity, compelling MNEs to rebalance exploration and exploitation activities.

Boundary conditions and illustrative indicators: This effect is expected to be more pronounced in sectors subject to strategic technology controls, including semiconductors, artificial intelligence, and advanced telecommunications. Potential indicators include levels of local R&D investment, intensity of international knowledge collaboration, patent co-authorship across borders, and measures of organizational absorptive capacity.

5.3 Network reconfiguration as a mediating mechanism

MNEs are networked organizations that depend on inter-firm and intra-firm relationships to generate innovation. Geopolitical disruptions and digital transitions both necessitate the reconfiguration of these networks. Firms must selectively decouple from politically risky partners while strengthening alliances in stable or strategically aligned regions (Hanisch, 2025). Network reconfiguration thus mediates how external disruptions influence innovation performance.

Digital technologies such as blockchain, cloud collaboration tools, and AI-based coordination systems enable this reconfiguration by lowering information asymmetries and enhancing trust in distributed systems. When MNEs actively restructure their networks through digital tools, they can buffer geopolitical shocks while sustaining innovation productivity.

Proposition 3: The reconfiguration of R&D networks mediates the relationship between disruption intensity (digital or geopolitical) and innovation performance.

Boundary conditions and illustrative indicators: The mediating effect may vary according to network complexity and the degree of dependence on international partnerships. Potential indicators

include alliance restructuring frequency, network centrality measures, geographic diversification of innovation partners, and innovation performance outcomes such as patent output, product introductions, or R&D productivity.

5.4 Digital governance and trust restoration

Geopolitical fragmentation often erodes trust among international partners (Yan and Piao, 2025). Concerns about data breaches, espionage, and regulatory noncompliance undermine the willingness to share critical knowledge (Li and Liu, 2021). To address these challenges, MNEs increasingly adopt digitally enabled governance mechanisms such as blockchain-based intellectual property (IP) verification, AI-driven contract monitoring, and distributed ledger systems for supply chain transparency. These technologies create verifiable, tamper-proof records that reduce opportunism and enhance accountability.

From a governance perspective, digital mechanisms substitute for relational trust when political or cultural trust is lacking. They allow MNEs to sustain collaboration in low-trust environments and expand innovation networks across contested geopolitical boundaries.

Proposition 4: Digitally enabled governance mechanisms (e.g., blockchain-based IP protection and AI-driven coordination) mitigate trust erosion in fragmented innovation ecosystems.

Boundary conditions and illustrative indicators: The effectiveness of digital governance mechanisms is likely to depend on technological maturity, regulatory acceptance, and partner willingness to adopt common standards. Potential indicators include levels of inter-organizational trust, frequency of knowledge-sharing activities, adoption of digital governance tools, and perceived collaboration effectiveness.

5.5 Dynamic capabilities and adaptive reconfiguration

Dynamic capabilities, the firm's capacity to sense opportunities and threats, seize them through timely decisions, and reconfigure assets accordingly, are critical in turbulent environments (Mero and Haapio, 2022). In the DEF context, dynamic capabilities are both digitally and geopolitically embedded. They depend on the firm's ability to integrate real-time data, anticipate policy changes, and orchestrate global innovation portfolios dynamically.

Firms with strong dynamic capabilities can leverage digital infrastructures to model geopolitical scenarios, simulate innovation bottlenecks, and adjust R&D allocations across regions. These firms not only survive disruptions but also exploit them as opportunities for competitive repositioning (Iftikhar et al., 2025).

Proposition 5: MNEs with strong dynamic capabilities are better able to convert digital affordances into sustained innovation under geopolitical uncertainty.

Boundary conditions and illustrative indicators: This relationship is expected to be strongest in highly dynamic environments characterized by rapid technological and regulatory change. Potential indicators include sensing capability, strategic flexibility, speed of resource

reallocation, digital investment intensity, and innovation performance under conditions of geopolitical uncertainty.

5.6 Feedback effects and institutional co-evolution

The relationship between digitalization, geopolitics, and innovation is not one-directional. As large MNEs adapt their strategies, they influence the institutional and geopolitical environment itself (Verbeke et al., 2025). Through lobbying, participation in international standard-setting bodies, and engagement in digital diplomacy, firms shape the regulatory regimes that govern technology and innovation (Smolak Lozano, 2025). Their adaptive responses can either reinforce or weaken global fragmentation. For example, firms advocating for open standards and interoperable systems contribute to global reintegration, while those pursuing proprietary or state-aligned models may exacerbate bifurcation (Fischer, 2025). This feedback loop underscores the co-evolutionary nature of digital and geopolitical systems.

Proposition 6: Feedback from firm-level adaptation influences macro-level institutional evolution, reinforcing or weakening global innovation interdependence.

Boundary conditions and illustrative indicators: The strength of this feedback effect may depend on firm size, technological influence, and participation in international governance processes. Potential indicators include involvement in technology standard-setting bodies, policy engagement activities, industry leadership positions, and observable changes in regulatory or institutional frameworks linked to firm initiatives.

5.7 Integrative summary

Collectively, these propositions provide a theoretically grounded and empirically testable model of global innovation governance under conditions of digitally enabled fragmentation. By specifying causal relationships, boundary conditions, and potential operational indicators, the framework establishes a foundation for future quantitative, qualitative, and mixed-methods research examining how multinational enterprises adapt to simultaneous digital and geopolitical disruption. They suggest that MNE success in a polarized global environment depends on the interplay between structural design (modularity), relational strategies (network reconfiguration and trust management), and capability development (absorptive and dynamic capabilities). Furthermore, firm-level adaptation is not merely reactive; it can reshape global institutions and technological trajectories.

The following section translates these theoretical insights into actionable managerial and policy implications, guiding how firms and governments can sustain innovation and value creation in an era of disruptive change.

6 Managerial and policy implications

The preceding theoretical propositions highlight how digital transformation and geopolitical fragmentation jointly reshape the governance of global innovation. This section translates these insights

into practical guidance for both managers and policymakers. It outlines strategies that can help multinational enterprises (MNEs) maintain resilience and innovation agility in turbulent environments while identifying policy measures that can support sustainable, cooperative global innovation systems.

6.1 Implications for managers

MNEs operating in an era of digitally enabled fragmentation face the complex challenge of sustaining innovation while mitigating political, technological, and institutional risks. The DEF framework provides several managerial insights for addressing these challenges:

- a *Design modular and flexible innovation architectures.* Managers should build modular R&D and innovation structures that allow rapid reconfiguration when disruptions occur. Modular architectures enable MNEs to redistribute R&D tasks across subsidiaries or partners depending on geopolitical developments. This structural flexibility minimizes exposure to regional shocks and enhances system-level resilience.
- b *Strengthen digital infrastructures for secure collaboration.* Investment in robust digital infrastructures, such as cloud-based R&D systems, blockchain verification for intellectual property, and AI-driven coordination platforms, can enable firms to sustain innovation despite fragmented institutional landscapes. These tools facilitate transparency, accountability, and coordination across dispersed teams, reducing transaction and trust costs.
- c *Balance global integration with local embeddedness.* Geopolitical fragmentation compels MNEs to localize certain R&D functions to comply with national regulations and data governance laws. Yet, excessive localization can weaken global knowledge synergies. Effective managers must pursue strategic ambidexterity, maintaining local responsiveness while sustaining cross-border knowledge flows. This balance requires the orchestration of hybrid governance models that combine regional autonomy with global digital integration.
- d *Cultivate dynamic and geopolitically embedded capabilities.* Firms must evolve beyond traditional dynamic capabilities to incorporate geopolitical awareness and digital fluency. This includes the ability to sense emerging policy shifts, simulate geopolitical scenarios through AI tools, and adapt innovation strategies accordingly. Leadership teams should establish dedicated risk-intelligence units that combine data analytics with geopolitical foresight.
- e *Institutionalize innovation diplomacy.* MNEs increasingly act as transnational policy intermediaries, shaping standards and regulatory outcomes. Managers should proactively engage in international dialogues on digital governance, ethical AI, and technology standards. By participating in these platforms, firms not only reduce uncertainty but also gain influence in shaping the emerging architecture of the global digital economy.
- f *Develop multi-scenario innovation portfolios.* Managers should adopt portfolio approaches to global innovation investments that account for multiple geopolitical futures. Diversifying R&D sites, partners, and supply chains across politically diverse regions reduces systemic dependency and provides strategic optionality. AI-based decision-support systems can

assist in continuously evaluating and reallocating resources based on evolving risks.

Together, these strategies emphasize a shift from efficiency-oriented global integration toward resilience-oriented global orchestration, an approach where digital technology becomes both a coordination mechanism and a risk management instrument. However, implementing these strategies is not without challenges. Investments in digital infrastructure, modular innovation systems, and geopolitical intelligence capabilities require substantial financial and organizational resources that may not be equally available across firms. Furthermore, efforts to enhance resilience may involve trade-offs with efficiency, as redundancy, regional diversification, and localized innovation activities can increase operational costs. Managers must therefore balance resilience objectives against performance considerations while recognizing that the optimal configuration may vary across industries and geopolitical contexts.

6.2 Implications for policymakers

The implications of digitally enabled fragmentation extend beyond firms. Policymakers play a critical role in ensuring that the benefits of digitalization and globalization are not lost amid geopolitical rivalries. Effective policy interventions can foster inclusive innovation, safeguard national interests, and maintain the integrity of global technological ecosystems.

- a *Promote innovation, diplomacy, and harmonization of global standards.* Governments should pursue cooperative frameworks that reduce fragmentation in digital standards, data governance, and intellectual property regimes. Initiatives such as digital free trade zones, cross-border data accords, and multilateral R&D partnerships can help sustain global knowledge flows while respecting sovereignty concerns.
- b *Invest in digital infrastructure and skills development.* The global digital divide remains a key source of inequality in innovation capacity. Policymakers should prioritize investments in broadband infrastructure, digital literacy, and advanced technical education. Strengthening digital readiness enhances national resilience and enables broader participation in global innovation networks.
- c *Encourage ethical and inclusive technological governance.* As AI, blockchain, and automation reshape industries, governments must ensure that innovation aligns with social and ethical norms. Policies that promote algorithmic transparency, data privacy, and equitable access to technology can build trust in digital systems and reduce the risk of geopolitical weaponization of innovation.
- d *Support cross-border research and talent mobility.* Geopolitical tensions have restricted the flow of scientists and engineers, undermining global learning. Policymakers should design visa programs, academic exchange initiatives, and joint innovation hubs that facilitate safe and regulated mobility. Collaborative research programs can serve as bridges across political divides.
- e *Build regional innovation coalitions.* In an increasingly multipolar world, regional blocs such as the African Union, the European Union, and ASEAN can act as intermediaries

promoting collective innovation resilience. Regional innovation coalitions can negotiate with global powers from a position of strength, ensuring fair access to emerging technologies.

- f *Develop policy tools for anticipatory governance.* Governments must move from reactive to anticipatory governance models. This requires integrating scenario analysis, foresight planning, and digital twin simulations into policy design. By anticipating the convergence of technological and geopolitical shifts, policymakers can prevent crises before they materialize.

Nevertheless, policymakers face significant tensions when balancing national security objectives with the benefits of international openness. Policies designed to protect strategic technologies may unintentionally restrict knowledge exchange, reduce innovation efficiency, and contribute to further fragmentation of global innovation systems. Effective governance therefore requires carefully calibrated interventions that safeguard national interests while preserving opportunities for international collaboration and technological diffusion.

6.3 Aligning business strategy and public policy

Effective governance of global innovation in the DEF context requires alignment between corporate strategy and public policy. However, such alignment is often difficult to achieve because firms and governments may pursue different priorities, time horizons, and risk perceptions (World Investment Report, 2025). While governments may prioritize national security, technological sovereignty, or industrial development, firms often prioritize innovation efficiency, market access, and shareholder value. Consequently, successful governance under conditions of digitally enabled fragmentation requires continuous dialogue, institutional coordination, and mechanisms that reconcile public and private interests.

7 Conclusion and future research directions

7.1 Summary of core insights

The central insight of this study is that digital transformation and geopolitical fragmentation should not be viewed as independent phenomena but as mutually reinforcing forces that jointly reshape the organization of global innovation. Digital technologies expand opportunities for knowledge integration, collaboration, and innovation across borders, while simultaneously creating new vulnerabilities associated with cybersecurity, digital sovereignty, and regulatory fragmentation. At the same time, geopolitical tensions increasingly influence access to technologies, markets, talent, and innovation partnerships.

Within this context, the Digitally Enabled Fragmentation (DEF) framework explains how multinational enterprises navigate the coexistence of digital integration and geopolitical fragmentation. The

framework demonstrates that successful adaptation depends on the interaction between macro-level disruptions, meso-level innovation network reconfiguration, and micro-level organizational capabilities. Rather than viewing fragmentation solely as a constraint, the framework highlights how firms can strategically leverage digital technologies to maintain innovation and resilience despite growing institutional complexity.

7.2 Theoretical contributions

This study makes three primary theoretical contributions. First, it introduces Digitally Enabled Fragmentation (DEF) as a novel conceptual construct that explains how multinational enterprises operate under simultaneous conditions of digital integration and geopolitical fragmentation. Second, it integrates Internalization Theory, the Knowledge-Based View, and Dynamic Capabilities Theory into a unified multi-level framework linking macro-level environmental disruptions, meso-level network adaptation, and micro-level organizational capabilities. Third, it develops a set of theoretically grounded propositions that provide a foundation for future empirical research on innovation, resilience, and global strategy in increasingly fragmented environments.

7.3 Managerial and policy relevance

For managers, the framework underscores that digital technologies must be leveraged not only for efficiency but also for resilience and risk mitigation. Effective governance of global innovation now requires balancing openness and autonomy, designing modular architectures, and cultivating geopolitical intelligence. For policymakers, the findings emphasize the need for international cooperation on digital standards, cross-border data governance, and innovation diplomacy to avoid deepening global technological divides. The alignment of corporate and policy agendas will determine whether the world's innovation systems evolve toward sustainable interdependence or enduring fragmentation. Collaboration between public and private actors in setting shared rules of the digital economy is, therefore, a strategic imperative. At the same time, the study recognizes that achieving such alignment is challenging. Firms and governments often pursue different objectives and operate under different constraints. Consequently, effective governance of global innovation will require ongoing negotiation, institutional experimentation, and adaptive policy frameworks capable of balancing national interests with the benefits of international collaboration.

7.4 Future research directions

While the DEF framework offers a comprehensive conceptual foundation, it invites empirical validation and theoretical refinement. Future research could explore several promising avenues:

- a *Empirical testing of propositions.* Researchers can employ quantitative and qualitative methods to examine the proposed relationships between digital modularity, network reconfiguration, and innovation performance. Cross-national surveys, multi-level modeling, and longitudinal analyses could reveal how different configurations of digital and geopolitical exposure affect firm outcomes.

- b *Comparative industry studies.* Sectoral differences in technological intensity, regulatory exposure, and value chain structure likely shape how DEF dynamics unfold. Comparative studies across semiconductors, biotechnology, renewable energy, and digital services could yield valuable insights into context-specific adaptation mechanisms.
- c *Case studies of MNE adaptation.* In-depth case research could trace how specific firms, such as Huawei, Siemens, or Alphabet, restructure their innovation networks and governance practices under digital geopolitical pressures. Such studies could illuminate micro-level decision processes and capability development trajectories.
- d *Network and ecosystem analysis.* Social network analysis, digital trace data, and ecosystem mapping could uncover how MNEs' global innovation partnerships evolve as fragmentation deepens. Network-based metrics may reveal which relational structures enhance or inhibit resilience.
- e *Policy experimentation and co-governance.* Future research can evaluate how emerging policy initiatives, such as regional technology alliances, cross-border data agreements, or public-private innovation labs, affect global innovation flows and governance. Comparative analysis of such initiatives across regions can inform policy design.
- f *Integration with environmental and social dimensions.* Digital-geopolitical disruptions intersect with sustainability and inclusion challenges. Future work could integrate environmental, social, and governance (ESG) concerns into the DEF framework to explore how global innovation strategies align with responsible business and sustainable development goals.

8 Conclusion

This study developed the Digitally Enabled Fragmentation (DEF) framework to explain how multinational enterprises navigate the simultaneous pressures of digital transformation and geopolitical fragmentation. The framework advances understanding of global innovation by demonstrating that digital technologies function both as mechanisms of integration and as sources of fragmentation, creating new strategic challenges and opportunities for multinational enterprises.

By integrating Internalization Theory, the Knowledge-Based View, and Dynamic Capabilities Theory, the study provides a multi-level explanation of how firms adapt through innovation network reconfiguration, capability development, and governance transformation. The resulting framework highlights the interconnected nature of macro-level geopolitical and technological disruptions, meso-level network adaptation, and micro-level organizational responses.

More broadly, the concept of Digitally Enabled Fragmentation offers a new lens through which scholars can examine the evolving relationship between globalization, digitalization, and innovation. As technological competition, regulatory divergence, and geopolitical uncertainty continue to reshape the global economy, understanding how firms maintain resilience, innovation, and value creation will become increasingly important. The DEF framework provides a

foundation for future theoretical and empirical research aimed at explaining these emerging dynamics and informing both managerial practice and public policy.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

MQ: Visualization, Software, Formal analysis, Project administration, Writing – original draft, Funding acquisition, Resources, Data curation, Validation, Investigation, Conceptualization, Methodology, Writing – review & editing, Supervision.

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