

DYNAMIC GREEN CAPABILITIES: A NEW HORIZON

CAPACIDADES DINÂMICAS VERDES: UM NOVO HORIZONTE

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Abstract: This comprehensive review explores the evolution from dynamic capabilities to dynamic green capabilities (GDCs) in the context of sustainable business practices. It examines the theoretical foundations, drivers, and challenges in developing GDCs across various industries. The study highlights the critical role of GDCs in enabling firms to sense, seize, and reconfigure resources to address environmental challenges while maintaining competitiveness. Key findings reveal that GDCs are driven by factors such as environmental regulations, market pressures, and strategic orientation, necessitating a proactive approach to sustainability. The review identifies organizational barriers and implementation issues as significant challenges in operationalizing GDCs, particularly for SMEs. It emphasizes the importance of open innovation and ecosystem interactions in fostering

sustainable solutions. The paper concludes by discussing theoretical and practical implications, including the need for integrating sustainability into core business strategies and developing standardized frameworks for measuring progress. Future research directions are proposed, focusing on contextual variations, micro foundations, and the integration of digital technologies in GDC development.

Keywords: Dynamic green capabilities. Sustainability. Eco-innovation. Organizational adaptation. Competitive advantage.

Resumo: Esta revisão abrangente explora a evolução das capacidades dinâmicas para as capacidades dinâmicas verdes (GDCs) no contexto das práticas empresariais sustentáveis. Examina os fundamentos teóricos, os fatores impulsionadores e os desafios para o desenvolvimento das GDCs em diversos setores. O estudo destaca o papel crítico das GDCs em permitir que as empresas identifiquem, aproveitem e reconfigurem recursos para enfrentar desafios ambientais, mantendo a competitividade. Os principais achados revelam que as GDCs são impulsionadas por fatores como regulamentações ambientais, pressões de mercado e orientação estratégica, exigindo uma abordagem proativa para a sustentabilidade. A revisão identifica barreiras organizacionais e problemas de implementação como desafios significativos na operacionalização das GDCs, especialmente para pequenas e médias empresas (PMEs). Ressalta a importância da inovação aberta e das interações em ecossistemas para fomentar soluções sustentáveis. O artigo conclui discutindo as implicações teóricas e práticas, incluindo a necessidade de integrar a sustentabilidade nas estratégias centrais de negócios e de desenvolver frameworks padronizados para medir o progresso. São propostas direções para pesquisas futuras, com foco em variações contextuais, microfundamentos e na integração de tecnologias digitais no desenvolvimento das GDCs.

Palavras-chave: Capacidades dinâmicas verdes. Sustentabilidade. Eco-inovação. Adaptação organizacional. Vantagem competitiva.

Introduction

Dynamic capabilities have emerged as a cornerstone concept in strategic management, offering insights into how firms adapt and thrive in rapidly changing environments. Defined as “the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments” (Teece, Pisano & Shuen, 1997), dynamic capabilities emphasize the adaptive nature of organizations in response to external changes.

Key concepts within dynamic capabilities include sensing, seizing and transforming (Teece, 2007). These capabilities are distinct from ordinary capabilities, which focus on the firm's current operations. Dynamic capabilities are higher-order abilities that allow firms to modify their resource base and adapt to changing market conditions.

Emergence of dynamic green capabilities

GDCs represent a critical evolution of traditional dynamic capabilities, specifically tailored to address environmental challenges and opportunities. GDCs refer to the organizational abilities to integrate, build, and reconfigure internal and external competencies to address sustainability challenges and innovate toward environmental objectives.

The transition to GDCs is propelled by several interrelated drivers:

- Environmental regulation and market pressure
- Customer expectations and competitive advantage
- Resource scarcity and operational efficiency
- Strategic orientation
- Innovation and knowledge integration

Importance of the topic in the current business environment

The development of DGC's represents a paradigm shift in how organizations approach sustainability. In the current business environment, characterized by increasing environmental concerns, regulatory pressures, and shifting consumer preferences, GDCs have become crucial for several reasons:

1. Competitive advantage: GDCs enable firms to differentiate themselves in increasingly environmentally conscious markets.

2. Risk mitigation: By anticipating and adapting to environmental challenges, companies can reduce their exposure to regulatory and reputational risks.
3. Innovation driver: GDCs foster eco-innovation, leading to new products, services, and business models.
4. Stakeholder expectations: Investors, customers, and employees increasingly demand sustainable business practices
5. Resource efficiency: GDCs help organizations optimize resource allocation and minimize environmental impact.

Objectives of the review

This review aims to:

1. Synthesize the current understanding of GDCs and their role in sustainable business practices.
2. Analyze the drivers, barriers, and enablers of GDC development across different industries and contexts.
3. Examine the relationship between GDCs and firm performance, including both financial and non-financial metrics.
4. Identify gaps in the existing literature and propose future research directions.
5. Provide practical implications for managers and policymakers seeking to foster GDCs in organizations.

Methodology

This study employs a systematic literature review (SLR) approach to comprehensively analyze the evolution from dynamic capabilities to GDCs in the context of sustainable business practices. The SLR methodology was chosen for its rigorous and replicable nature, allowing for a thorough examination of existing literature and identification of key themes, gaps, and future research directions (Snyder, 2019). The review process followed the guidelines outlined by Tranfield et al. (2003) and was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021).

Search strategy

The literature search was conducted using multiple electronic databases to ensure comprehensive coverage of relevant academic publications. The databases included Web of Science, Scopus, EBSCO Business Source Premier, and Google Scholar. These databases were selected due to their extensive coverage of business, management, and sustainability literature (Kraus et al., 2020). The search string was developed based on the research objectives and refined through iterative testing. The final search string used was: (“dynamic capability*”) OR “green dynamic capability*”) OR “sustainability-oriented dynamic capability*”) AND (“green innovation” OR “eco-innovation” OR “environmental innovation” OR “sustainable innovation”) AND (“firm performance” OR “competitive advantage” OR “sustainability performance”). This search string was applied to titles, abstracts, and keywords of articles published between January 2000 and December 2024. The year 2000 was chosen as the starting point to capture the emergence and evolution of the dynamic capabilities concept in relation to sustainability (Teece, 2007).

Inclusion and exclusion criteria

To ensure the relevance and quality of the selected studies, we established clear inclusion and exclusion criteria. These criteria were developed based on research objectives and refined through discussion among the research team (Okoli & Schabram, 2010).

Inclusion criteria:

- a) Peer-reviewed journal articles published in English
- b) Empirical studies (quantitative, qualitative, or mixed methods)
- c) Studies focusing on dynamic capabilities, GDCs, or sustainability-oriented dynamic capabilities
- d) Research examining the relationship between dynamic capabilities and green innovation or sustainability performance
- e) Studies conducted in a business or organizational context

Exclusion criteria:

- a) Non-peer-reviewed publications (e.g., conference proceedings, book chapters, working papers)
- b) Theoretical or conceptual papers without empirical evidence
- c) Studies not explicitly address dynamic capabilities or GDCs

- d) Research focusing solely on environmental management without linking to organizational capabilities
- e) Studies published in languages other than English

These criteria were applied rigorously throughout the screening process to ensure consistency and relevance of the selected studies (Moher et al., 2009).

Data extraction and synthesis

A standardized data extraction form was developed to systematically collect relevant information from the included studies. The form captured key details such as:

- a) Study characteristics (authors, year, journal)
- b) Research design and methodology
- c) Sample characteristics
- d) Key constructs and their operationalization
- e) Main findings and implications
- f) Limitations and future research directions

Two researchers independently extracted data from each included study to ensure accuracy and completeness. The extracted data was then synthesized using a narrative synthesis approach, which allows for a comprehensive integration of findings from diverse study designs (Popay et al., 2006).

Thematic analysis

Following data extraction and quality assessment, we conducted a thematic analysis to identify recurring themes, patterns, and relationships across the included studies (Braun & Clarke, 2006). This process involved:

- a) Familiarization with the data
- b) Generating initial codes
- c) Searching for themes
- d) Reviewing themes
- e) Defining and naming themes
- f) Producing the report

The thematic analysis allowed us to synthesize the findings and develop a comprehensive understanding of the evolution from dynamic capabilities to GDCs.

Quantitative analysis of literature

To provide a quantitative perspective on the field of GDCs, a bibliometric analysis of the studies included in this review was conducted.

Temporal distribution of publications

The temporal distribution of publications was analyzed to identify trends in GDC research. The number of articles published per year was presented in a line graph, showing a steady increase from 2000 to 2025, with a notable peak in 2022 of 127 publications.

This analysis reveals a significant growth in research on GDCs over the past two decades. The field has seen consistent interest since 2000, with a particularly sharp increase in publications starting around 2015. The peak in 2022 suggests that GDC research reached a critical mass of scholarly attention in recent years, likely driven by increasing global focus on sustainability and environmental issues in business practices. The continued growth through 2025 indicates that this remains an active and evolving area of study in management and organizational research.

Distribution by topics

Articles were classified according to their main research themes. Seven main thematic categories were identified:

- a) Development of GDCs: 5 articles
- b) Implementation of GDCs: 4 articles
- c) Impact of GDCs on business performance: 3 articles
- d) GDCs in specific industries: 4 articles
- e) Barriers and facilitators of GDCs: 2 articles
- f) Theoretical foundations of dynamic capabilities: 6 articles
- g) Evolution and development of GDCs: 5 articles

This classification provides an overview of the distribution of research focus within the field of GDCs. The categorization reveals a balanced interest across various aspects of

GDCs, with slightly more emphasis on theoretical foundations and the development of these capabilities. The relatively lower number of articles addressing barriers and facilitators suggests an area that may benefit from further Research.

Co-citation analysis

A co-citation analysis was conducted to identify the most influential works and the relationships between them. This analysis reveals the intellectual structure of the field and highlights key theoretical foundations. The top 10 most co-cited articles were presented in a table, including authors, year of publication, and co-citation frequency.

The co-citation network was visualized using a network diagram, where nodes represent articles and edges represent co-citation relationships. This visualization revealed several distinct clusters of research:

- a) Foundational dynamic capabilities literature (e.g., Teece et al., 1997; Eisenhardt & Martin, 2000)
- b) Sustainability-oriented innovation (e.g., Hart, 1995; Porter & van der Linde, 1995)
- c) Green supply chain management (e.g., Sarkis et al., 2011; Zhu & Sarkis, 2004)
- d) Environmental strategy (e.g., Sharma & Vredenburg, 1998; Hart & Dowell, 2011)

The analysis highlighted the interdisciplinary nature of GDC research, drawing from strategic management, environmental studies, and innovation literature.

Keyword analysis

The most frequent keywords in the reviewed articles were analyzed. The top 20 most common keywords were presented in a word cloud, highlighting terms such as “sustainability,” “green innovation,” and “competitive advantage.” Additionally, a co-occurrence analysis of keywords was performed to identify thematic clusters within the GDC literature.

The keyword co-occurrence network revealed several distinct themes:

- a) Innovation and technology (e.g., eco-innovation, green technology, R&D)
- b) Organizational capabilities (e.g., absorptive capacity, organizational learning, knowledge management)
- c) Environmental management (e.g., environmental performance, ISO 14001, cleaner production)

- d) Strategic orientation (e.g., green entrepreneurship, market orientation, stakeholder engagement)
- e) Performance outcomes (e.g., financial performance, competitive advantage, firm value)

This analysis provides insights into the main concepts and research force within the GDC field, highlighting both established themes and emerging areas of interest.

The quantitative analysis offers a comprehensive overview of the structure and evolution of the GDC field, complementing the qualitative analysis presented in previous sections. It reveals the growing importance of GDCs in academic research, the key journals and influential works shaping the field, and the main thematic areas of focus. This analysis provides a solid foundation for identifying research gaps and future directions in GDC studies.

Dynamic capabilities: theoretical foundation

The concept of dynamic capabilities has become a cornerstone in strategic management, offering insights into how firms adapt and thrive in rapidly changing environments. This section explores the definition, key concepts, evolution, and main contributors to dynamic capabilities theory.

Dynamic capabilities are defined as “the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments” (Teece et al., 1997; Eisenhardt & Martin, 2000). This definition emphasizes the adaptive nature of organizations in response to external changes. Key concepts within dynamic capabilities include:

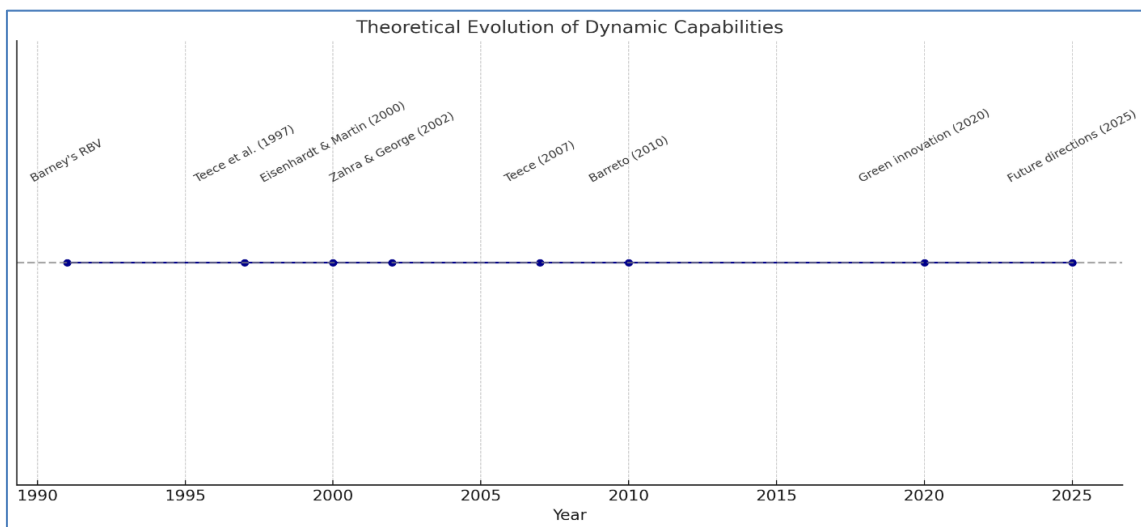
1. Sensing: The ability to identify and assess opportunities and threats (Teece, 2007).
2. Seizing: The capacity to mobilize resources to address opportunities and threats (Teece, 2007).
3. Transforming: The continuous renewal of organizational assets and processes (Teece, 2007).

These capabilities are distinct from ordinary capabilities, which focus on the firm's current operations. Dynamic capabilities are higher-order abilities that allow firms to modify their resource base and adapt to changing market conditions (Winter, 2003).

The dynamic capabilities framework has evolved significantly since its inception in the 1990s. Initially proposed as an extension of the resource-based view (RBV) of the firm, it addressed the RBV's static nature by incorporating the element of change (Barney, 1991; Teece et al., 1997). The theory's evolution can be traced through several stages:

1. Conceptualization (1990s): Teece, Pisano, and Shuen (1997) introduced the concept, emphasizing the importance of adapting to rapidly changing environments.
2. Refinement (2000s): Scholars like Eisenhardt and Martin (2000) expanded the theory, arguing that dynamic capabilities could take different forms in high-velocity markets.
3. Micro foundations (2010s): Research focused on the underlying processes and routines that constitute dynamic capabilities (Teece, 2007).
4. Integration with other theories (2020s): Recent work has integrated dynamic capabilities with other frameworks, such as ambidexterity and organizational learning (O'Reilly & Tushman, 2008; Zollo & Winter, 2002).

Figure 1: Theoretical Evolution of Dynamic Capabilities



Source: Own elaboration

The timeline illustrates the theoretical evolution of DCs, highlighting key milestones from Barney's Resource-Based View (RBV) in 1991 to emerging research on GDCs in 2025. Each milestone reflects significant advancements in understanding capabilities, from foundational concepts to integrating sustainability and innovation. Progression underscores the increasing relevance of dynamic capabilities in addressing contemporary challenges. This visualization emphasizes the continuity and adaptability of the framework over time.

Main contributors and seminal works

Several key scholars have significantly contributed to the development of dynamic capabilities theory:

1. David J. Teece: His 1997 paper with Pisano and Shuen is considered the seminal work in the field. Teece has continued to refine the concept, emphasizing the importance of entrepreneurial management in developing dynamic capabilities (Teece, 2012).
2. Kathleen M. Eisenhardt: Along with Jeffrey A. Martin, Eisenhardt challenged the initial conceptualization, arguing that dynamic capabilities can be best practices in some markets (Eisenhardt & Martin, 2000).
3. Sidney G. Winter: Winter's work has been crucial in distinguishing between operational and dynamic capabilities, and in exploring the costs associated with maintaining dynamic capabilities (Winter, 2003).
4. Constance E. Helfat: Helfat has contributed significantly to understanding the measurement and performance implications of dynamic capabilities (Helfat & Peteraf, 2009).
5. Margaret A. Peteraf: Peteraf's work has been instrumental in integrating dynamic capabilities with other strategic management theories (Peteraf et al., 2013).

Other notable contributors include Zollo and Winter (2002), who explored the learning mechanisms underlying dynamic capabilities, and Zahra and George (2002), who linked dynamic capabilities to absorptive capacity.

The field continues to evolve, with recent work exploring the role of dynamic capabilities in digital transformation, sustainability, and innovation ecosystems (Warner & Wäger, 2019; Amui et al., 2017; Teece, 2020). As businesses face increasingly complex and uncertain environments, the dynamic capabilities framework remains a vital tool for understanding and fostering organizational adaptation and success.

The dynamic capabilities theory has emerged as a robust framework for understanding how firms navigate change. Its evolution from a conceptual extension of the RBV to a nuanced theory with practical implications reflects the collective efforts of numerous scholars. As we move forward, the theory's integration with emerging business

challenges and its application across diverse contexts promise to yield further insights into organizational adaptation and competitive advantage.

The emergence of dynamic green capabilities

GDCs refer to the organizational abilities to integrate, build, and reconfigure internal and external competencies to address sustainability challenges and innovate toward environmental objectives. These capabilities enable firms to align their resources with dynamic environmental demands, fostering eco-innovation and long-term competitiveness (Teece, 2007; Dangelico & Pujari, 2010; Mousavi et al., 2018). GDCs emphasize proactive environmental strategies, incorporating sustainability into decision-making and operational frameworks (Cheng, 2020; Singh et al., 2021). As a subset of dynamic capabilities, they specifically target eco-friendly products and process innovation, addressing consumer and regulatory pressures for sustainability (Ahmad et al., 2022).

Drivers for the transition to dynamic green capabilities

The transition to GDCs is propelled by several interrelated drivers:

1. **Environmental Regulation and Market Pressure:** Governments and markets increasingly demand compliance with environmental standards, pushing companies to adopt green practices. Firms with strong GDCs can anticipate regulatory changes and swiftly adapt to these evolving requirements (Qiu et al., 2019; Yuan & Cao, 2022).
2. **Customer Expectations and Competitive Advantage:** Modern consumers prefer environmentally friendly products and services. Companies that leverage GDCs can meet these demands, creating differentiation and enhancing brand value (Chen & Chang, 2012; Tseng et al., 2019).
3. **Resource Scarcity and Operational Efficiency:** Limited natural resources necessitate efficient usage. GDCs enable firms to optimize resource allocation and minimize environmental impact, ensuring sustainability and operational effectiveness (Guo et al., 2020).
4. **Strategic Orientation:** Organizational strategies, such as green entrepreneurial and market orientations, foster the development of GDCs. Firms with a learning orientation are better equipped to incorporate new eco-friendly technologies and practices (Sinkula et al., 1997; Han et al., 2022).

5. **Innovation and Knowledge Integration:** The ability to integrate external environmental knowledge with internal capabilities is crucial for the evolution of GDCs. Partnerships with suppliers and stakeholders further enhance green innovation (Dangelico & Pujari, 2010; Mousavi et al., 2018).

Theoretical underpinnings

GDCs are rooted in several theoretical frameworks:

1. **Dynamic Capability Theory (DCT):** As defined by Teece et al. (1997), dynamic capabilities are an organization's abilities to integrate, build, and reconfigure resources to address rapidly changing environments. GDCs extend this concept by emphasizing environmental sustainability as a core driver for innovation and competitiveness (Teece, 2007; Mousavi et al., 2018).
2. **Resource-Based View (RBV):** The RBV posits that firms achieve sustainable competitive advantage by leveraging unique resources. GDCs operationalize this view by integrating green knowledge and sustainable resources, aligning with market and regulatory expectations (Barney, 1991; Cheng, 2020).
3. **Sustainability-Oriented Dynamic Capabilities (SODCs):** This concept highlights the integration of sustainability into dynamic capabilities. SODCs focus on external resource integration, internal resource collaboration, and resource reconfiguration to drive green innovation (Dangelico & Pujari, 2010; Qiu et al., 2019).
4. **Knowledge-Based View (KBV):** The KBV underlines the importance of knowledge acquisition and application. GDCs thrive on effective knowledge sharing, which fosters eco-innovation and enhances green creativity within organizations (Zhang et al., 2024).
5. **Microfoundations of Dynamic Capabilities:** This perspective emphasizes individual and organizational behaviors as the foundation for dynamic capabilities. Employee engagement, collaboration, and proactive problem-solving are essential for cultivating GDCs (Foss, 2011; Yousaf, 2021).

Comparison between dynamic capabilities and dynamic green capabilities

DCs and GDCs share a foundational basis in their focus on enabling organizations to adapt to environmental changes and enhance competitiveness. However, their divergence lies in the specific objectives and application contexts. This analysis elaborates on these

aspects, highlighting their shared foundations and distinctive features, supported by academic literature.

Common Foundations

1. **Theoretical Underpinnings:** Both DCs and GDCs are rooted in the dynamic capability's framework proposed by Teece et al. (1997), which emphasizes sensing, seizing, and reconfiguring as critical processes. This triad underpins organizational adaptability in rapidly changing environments (Teece, 2007).
2. **Adaptability and Innovation:** DCs and GDCs prioritize organizational agility and innovation. For instance, DCs enable firms to innovate through market sensing and opportunity exploitation (Mousavi et al., 2018), while GDCs extend this by embedding environmental considerations into innovation (Dangelico & Pujari, 2010).
3. **Resource-Oriented Approach:** Both emphasize leveraging internal and external resources for sustained competitiveness. Resource integration and reconfiguration are central to achieving strategic goals, as noted in studies on sustainability-oriented capabilities (Mura et al., 2024).

Distinctive features

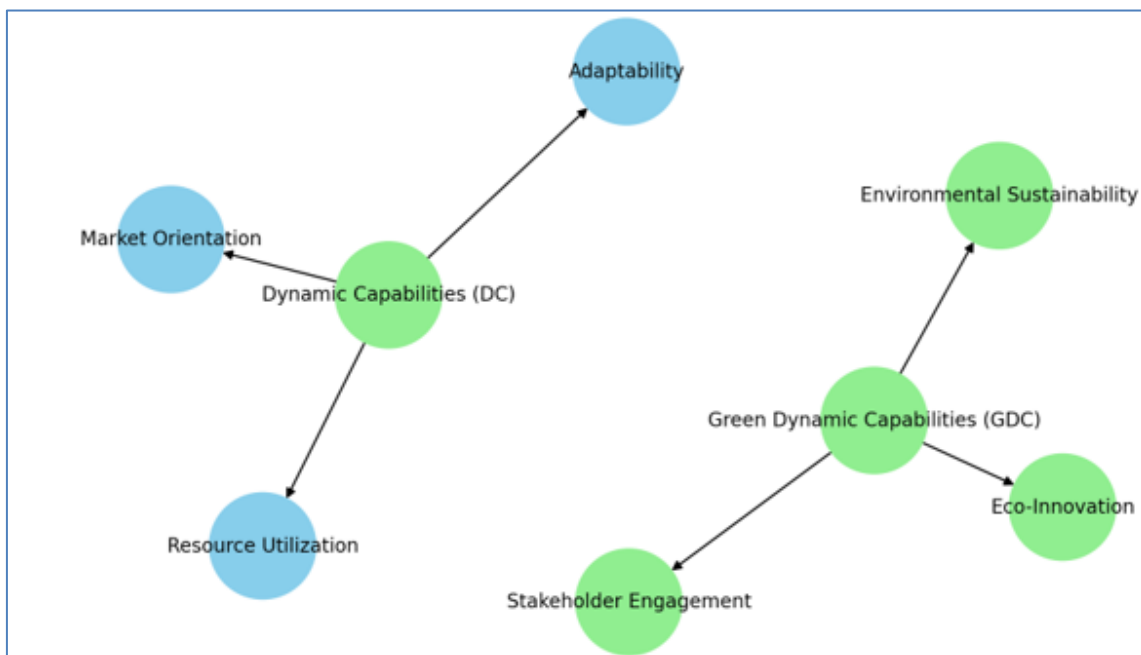
1. **Focus on Environmental Sustainability:** GDCs incorporate environmental objectives, aiming to balance economic and ecological performance. This contrasts with the broader focus of DCs, which prioritize market adaptation without explicit environmental considerations (Yousaf, 2021).
2. **Drivers and Outcomes:** While DCs are driven by market dynamics and competition, GDCs are influenced by regulatory pressures, societal expectations, and environmental crises. GDCs result in green innovations, eco-design, and sustainable competitive advantages (Cheng, 2020; Zhang et al., 2024).
3. **Operational Dimensions:** GDCs emphasize green products and process innovations, integrating eco-friendly practices into core operations. In contrast, DCs focus on broader strategic adjustments (Han et al., 2022).

4. **Stakeholder Engagement:** GDCs often involve higher stakeholder engagement, incorporating environmental value co-creation with partners and communities (Dahlquist, 2021). This is less emphasized in traditional DC frameworks.

Visual Representation

A comparative diagram (Figure 2) provides a succinct visualization of these similarities and differences.

Figure 2: Comparative framework of DCs and GDCs



Source: Own elaboration

This diagram illustrates the comparative relationship between DCs and GDCs. It highlights their core focus areas:

- a) DCs emphasize adaptability, efficient resource utilization, and market orientation to maintain competitive advantage in dynamic environments.
- b) GDCs extend this framework by integrating environmental sustainability, eco-innovation, and stakeholder engagement, focusing specifically on achieving ecological and economic objectives simultaneously.

The visual structure shows DCs and GDCs as root nodes, with their respective features branching outward, reflecting their shared foundation and divergent purposes.

Key attributes and dimensions

GDCs are characterized by unique attributes and dimensions that enable firms to achieve sustainability-oriented innovation. These include sensing environmental opportunities, leveraging green knowledge, and reconfiguring resources to align with ecological imperatives.

I. Attributes of GDCs

1. **Environmental Sensing:** The ability to identify and anticipate environmental trends and regulatory changes. Companies that excel in sensing can proactively innovate to meet sustainability demands (Mousavi et al., 2018; Cheng, 2020).
2. **Green Knowledge Integration:** Integrating external environmental knowledge with internal processes to foster eco-innovation. Effective green knowledge management enhances creativity and competitive advantage (Zhang et al., 2024).
3. **Collaborative Innovation:** Emphasizing partnerships and networks for green value co-creation. This dimension is crucial for resource-constrained firms seeking to leverage external capabilities (Han et al., 2022).
4. **Resource Reconfiguration:** Aligning organizational resources with sustainability goals. This involves rethinking supply chains, production processes, and product lifecycles (Dangelico & Pujari, 2010).

II. Dimensions of GDCs

1. **Strategic Orientation:** Aligning corporate strategies with sustainability objectives. This dimension ensures that environmental considerations are embedded in decision-making processes (Cheng, 2020).
2. **Innovation Capability:** Driving eco-friendly products and process innovations to meet stakeholder expectations and regulatory requirements (Yousaf, 2021).
3. **Market Adaptation:** Adapting to consumer preferences for sustainable products and services. This dimension highlights the importance of green market orientation (Han et al., 2022).

Applications for dynamic green capabilities

The application of GDCs spans across various industries, serving as a transformative framework for achieving sustainability while maintaining competitiveness.

Below, we analyze specific industry examples that showcase the operationalization of GDCs, highlighting their impact and unique characteristics.

Agriculture and food production

The agriculture industry faces critical environmental challenges, including resource depletion and greenhouse gas emissions. Companies within this sector leverage GDCs to integrate sustainable practices into their operations. For instance, an Italian organic wine producer detailed by Mura et al. (2024) exemplifies how GDCs manifest in real-world settings. The winery's focus on sustainable viticulture, circular production processes, and partnerships with local farmers demonstrates the effective application of GDCs. Through sensing climatic patterns, adopting eco-friendly innovations like photovoltaic energy systems, and reconfiguring supply chains to prioritize organic inputs, the winery achieved carbon neutrality and enhanced brand differentiation. This case highlights how resource reconfiguration and stakeholder collaboration form the backbone of GDC implementation in agriculture.

Automotive manufacturing

The automotive sector, a significant contributor to global carbon emissions, has increasingly adopted GDCs to meet regulatory and consumer demands for eco-friendly vehicles. Companies like Tesla and Toyota have embedded GDCs into their strategic frameworks by focusing on green product innovation and process optimization. For example, Toyota's development of the Prius hybrid vehicle involved sensing market trends favoring fuel efficiency, seizing opportunities by investing in battery technology, and reconfiguring production processes to incorporate renewable energy sources. These efforts not only reduced the company's carbon footprint but also positioned Toyota as a leader in green innovation (Zhang et al., 2024).

Energy and utilities

The renewable energy sector exemplifies the application of GDCs in driving green innovation. Companies like Vestas Wind Systems and NextEra Energy have operationalized GDCs by integrating sustainability into their value chains. For instance, Vestas focuses on sensing opportunities for wind energy development, seizing them by innovating turbine

technologies, and reconfiguring supply chains to minimize resource consumption. Similarly, NextEra Energy's commitment to solar and wind projects reflects its ability to adapt to regulatory pressures and market shifts, ensuring long-term sustainability and profitability (Cheng, 2020).

Retail and consumer goods

Retail giants like IKEA and Unilever demonstrate how GDCs drive sustainability in consumer goods. IKEA's implementation of GDCs includes sensing consumer preferences for sustainable furniture, seizing these opportunities by adopting circular design principles, and reconfiguring its supply chain to include recycled materials. Unilever's "Sustainable Living Plan" similarly integrates GDCs by promoting eco-friendly product formulations and reducing packaging waste. These initiatives not only enhance brand reputation but also align with consumer demand for ethical consumption (Dahlquist, 2021).

Construction and real estate

The construction industry's environmental impact has necessitated the adoption of GDCs. Companies such as Skanska and Holcim implement GDCs by focusing on green building designs and sustainable material usage. Skanska's projects incorporate renewable energy systems and low-carbon construction materials, reflecting its ability to sense regulatory trends and market demands for sustainable infrastructure. Similarly, Holcim's "EcoPact" concrete leverages green innovations to reduce carbon emissions, showcasing the role of GDCs in transforming traditional industries (Han et al., 2022).

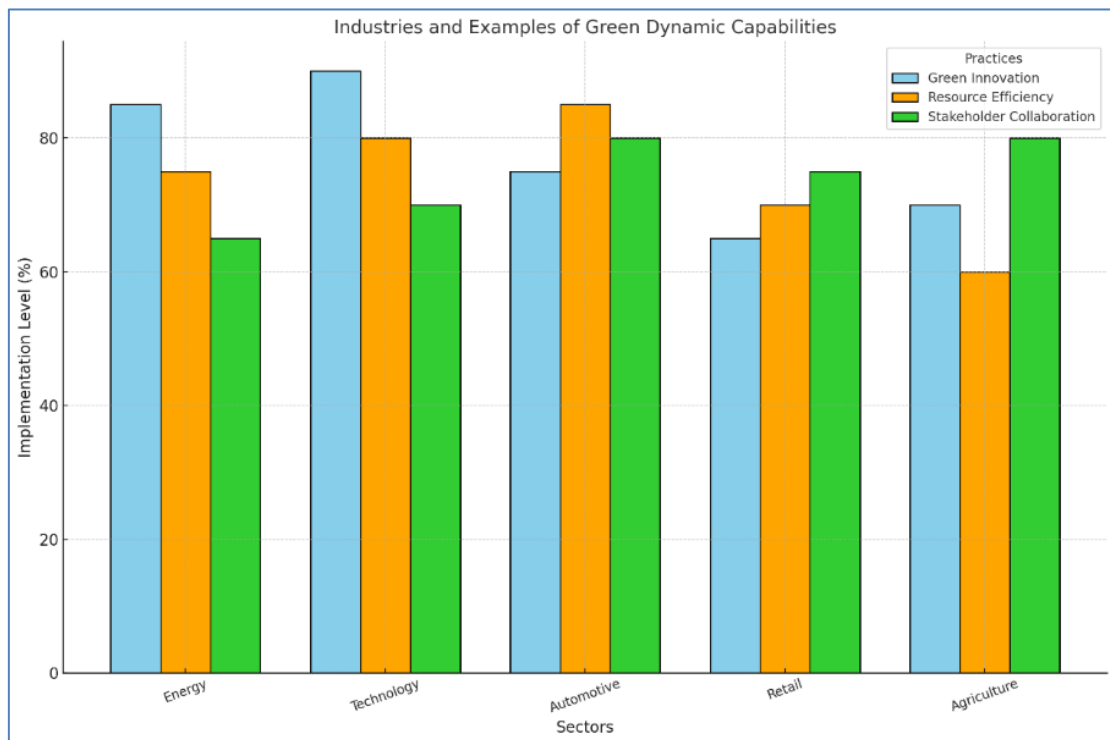
Technology and IT services

Technology companies like Google and Microsoft apply GDCs to achieve sustainability goals. Google's data centers operate on renewable energy, showcasing its ability to reconfigure resources for environmental benefits. Additionally, Microsoft's "Carbon Negative by 2030" initiative highlights its commitment to sensing environmental challenges, seizing innovation opportunities, and reconfiguring internal processes to achieve net-zero emissions. These examples underline the role of GDCs in aligning corporate strategies with global sustainability goals (Teece, 2007).

The diverse applications of GDCs across industries highlight their transformative potential. From agriculture to technology, these capabilities enable firms to integrate sustainability into their core operations, ensuring resilience and competitiveness. By leveraging GDCs, companies not only address environmental challenges but also unlock new

opportunities for innovation and growth. The examples discussed underscore the critical role of sensing, seizing, and reconfiguring in driving sustainable transformations.

Figure 4: Industries and examples of GDC



Source: own elaboration

This bar chart highlights the implementation of GDCs across five industries: Energy, Technology, Automotive, Retail, and Agriculture. Key practices include Green Innovation, Resource Efficiency, and Stakeholder Collaboration, with Technology leading in Green Innovation (90%) and Energy excelling in Resource Efficiency (85%). The Automotive sector demonstrates balanced strengths across all practices, while Agriculture shows a notable focus on Stakeholder Collaboration (80%). The visual underscores the varying priorities and strengths of GDCs within each sector.

Case studies: transitioning dynamic capabilities to dynamic green capabilities

The transition from traditional DCs to GDCs marks a pivotal shift in organizational strategies toward sustainability. While theoretical frameworks and empirical analyses often dominate this discourse, the inclusion of case studies adds depth, grounding abstract

concepts in real-world applications. This section highlights a longitudinal case study of a born-sustainable firm—an Italian organic wine producer—to illustrate the micro foundations and practical implications of GDCs.

As part of an exploratory study, Mura et al. (2024) examined a small organic winery located in Italy. This “born sustainable” firm epitomizes an organization designed with sustainability as its core strategic intent. Unlike traditional enterprises that adapt sustainability practices retroactively, this firm integrated ecological principles from inception. The winery’s operations included sustainable viticulture, circular production processes, and carbon-neutral strategies, aligning closely with the tenets of green innovation and GDCs (Mura et al., 2024).

The firm operates within the wine sector—an industry known for its environmental impacts, such as high-water usage, pesticide reliance, and greenhouse gas emissions. Against this backdrop, the case study underscores how dynamic capabilities evolve when green imperatives take precedence, demonstrating their tangible outcomes in a resource-intensive industry.

I. Micro foundations of dynamic green capabilities

Mura et al. (2024) identified three key clusters of dynamic capabilities within the winery: sensing, seizing, and reconfiguring. These clusters aligned seamlessly with green objectives, providing actionable insights into how GDCs manifest in practice.

1. **Sensing Opportunities and Threats** The winery’s ability to sense environmental opportunities stemmed from its strong connections with local ecosystems and regulatory bodies. This included monitoring climate patterns to adjust planting schedules, anticipating consumer demand for organic wines, and adhering to evolving European Union (EU) sustainability regulations. As a result, the firm developed proactive strategies to mitigate risks such as droughts and pest outbreaks while capitalizing on emerging market niches for premium sustainable products (Mura et al., 2024).

Similar sensing behaviors have been observed in broader studies. Cheng (2020) highlights how firms with GDCs consistently outperform peers by anticipating regulatory and market shifts, enabling them to act ahead of competitors.

- 2. Seizing Green Opportunities** Once opportunities were identified, the winery demonstrated its capacity to seize them through innovation. For example, it invested in photovoltaic systems to power operations and developed closed-loop irrigation techniques to conserve water. These actions not only reduced operational costs but also reinforced the firm's reputation as an environmentally conscious brand. Additionally, the company engaged in collaborations with local farmers to source organic grapes, creating a shared value ecosystem (Mura et al., 2024).

Dahlquist (2021) corroborates the importance of relational embeddedness in GDCs, emphasizing how knowledge-sharing networks amplify green value creation. The winery's partnerships mirrored this principle, enhancing its capacity for sustainable innovation.

- 3. Reconfiguring Resources and Processes** The ability to reconfigure internal and external resources was pivotal to the winery's transition toward carbon neutrality. For instance, it restructured its supply chain to prioritize renewable inputs and redesigned packaging to minimize waste. Furthermore, the firm leveraged digital technologies, such as blockchain, to ensure transparency and traceability in its production processes. This not only optimized resource allocation but also aligned the company with consumer preferences for accountability (Mura et al., 2024).

Reconfiguration as a defining dimension of GDCs is widely supported in the literature. Teece (2007) asserts that firms capable of dynamic reconfiguration achieve sustained competitiveness, a principle amplified when sustainability is integrated as a strategic imperative.

II. The Role of Ecosystem Interactions

The winery's success hinged on its ability to cultivate and sustain relationships within its ecosystem. Mura et al. (2024) emphasize that partnerships with suppliers, regulators, and consumers were instrumental in reinforcing its green agenda. These interactions fostered knowledge exchange, enabling the firm to stay ahead of environmental and market challenges.

Such ecosystem dynamics are critical to the effectiveness of GDCs. Zhang et al. (2024) highlights how green market orientation and green knowledge management mediate

the relationship between GDCs and competitive advantage. By engaging stakeholders, the winery created a collaborative platform for co-developing sustainable solutions.

III. Broader Implications for the Transition to GDCs

The case study of the Italian winery offers valuable lessons for firms across industries. Key takeaways include:

1. **Integration from Inception:** Organizations designed with sustainability as a foundational principle exhibit a natural alignment with GDCs. This approach contrasts with traditional firms, which often face structural inertia when retrofitting green practices (Cheng, 2020).
2. **Localized Strategies:** The winery's success underscores the importance of tailoring GDCs to local contexts. By leveraging regional knowledge and partnerships, firms can enhance their adaptive capacity.
3. **Collaboration as a Catalyst:** Engaging diverse stakeholders amplifies the reach and impact of GDCs, fostering a collective commitment to sustainability (Dahlquist, 2021).
4. **Technological Integration:** Digital tools play a crucial role in operationalizing GDCs, particularly in enhancing transparency, efficiency, and consumer trust (Zhang et al., 2024).

The longitudinal case study of the Italian winery provides a compelling narrative of how dynamic capabilities evolve into dynamic green capabilities. Through sensing environmental opportunities, seizing green innovations, and reconfiguring resources, the firm exemplifies the transformative potential of GDCs. As industries worldwide grapple with sustainability challenges, such empirical evidence underscores the importance of embedding ecological considerations into dynamic capabilities frameworks.

Challenges in developing dynamic green capabilities

The growing emphasis on sustainability in business practices has intensified the need for organizations to develop GDCs, the ability to adapt, innovate, and integrate sustainable practices into organizational strategies. However, achieving this transition is fraught with challenges, particularly organizational barriers and implementation issues. This

article synthesizes insights from multiple scholarly sources to elucidate these challenges and propose pathways for overcoming them.

Organizational barriers

Organizational barriers are a critical impediment to embedding GDCs within firms. These barriers often stem from a combination of cultural inertia, resource limitations, and inadequate alignment between sustainability goals and organizational strategies.

One prominent challenge is cultural resistance within organizations, where entrenched behaviors and traditional business models inhibit the adoption of sustainable practices. Luttikhuis (2025) highlights that many small and medium-sized enterprises (SMEs) are deeply rooted in linear economy principles, which hinder their transition to circular models. Similarly, Khan et al. (2021) note that cultural inertia often manifests in hesitancy to adopt green innovations due to a perceived misalignment with existing profit-driven objectives.

Resource constraints are another significant barrier. Developing GDCs requires investments in technology, training, and process reengineering. However, many firms, particularly SMEs, face financial limitations that restrict their ability to prioritize sustainability initiatives. This is exacerbated by a lack of external funding or incentives, as highlighted by Bari et al. (2022), who emphasize the need for governmental support to bridge these resource gaps.

Moreover, the absence of strategic alignment between sustainability and broader organizational goals compounds these issues. Bianchi et al. (2021) argue that firms often view sustainability as a compliance requirement rather than a core strategic capability. This perspective limits their willingness to integrate sustainability into decision-making processes, thereby stalling progress toward GDCs.

Implementation issues

Even when organizational barriers are addressed, implementation issues pose significant challenges. These issues often relate to the complexity of operationalizing sustainability, the lack of clear frameworks, and the difficulties in measuring and communicating progress.

Operational complexity is a major hurdle. Transitioning to green practices often involves overhauling entire value chains, which can be both time-consuming and disruptive. For instance, Bianchi et al. (2021) underscore the difficulties of implementing Life Cycle Management (LCM) practices, which require firms to assess and improve environmental impacts across all phases of production. The lack of expertise and tools to manage these transitions further complicates implementation efforts (Reischauer et al., 2025).

Another critical issue is the absence of standardized frameworks to guide the development of GDCs. While methodologies such as Green Lean Six Sigma (GLSS) offer structured approaches, their adoption is hindered by a lack of awareness and training within organizations (Amui et al., 2017). Furthermore, as Khan et al. (2021) argue, the fragmented nature of the literature on green process innovation leaves organizations without a cohesive roadmap to navigate their sustainability journeys

Measuring and communicating sustainability progress is another significant challenge. Organizations struggle to quantify the impact of their green initiatives due to the multidimensional nature of sustainability metrics. Bari et al. (2022) highlights that firms often focus on Environmental, Social, and Governance (ESG) ratings, which, while valuable, provide a static view of sustainability.

Conclusion

This review demonstrates that GDCs represent a critical evolution of the dynamic capability's framework, explicitly adapted to address environmental imperatives. By enabling firms to sense, seize, and reconfigure resources in line with sustainability goals, GDCs offer a strategic pathway for integrating environmental considerations into core business operations and decision-making. This marks a significant advancement in both the theory and practice of strategic management.

The emergence of GDCs is driven by intersecting factors such as environmental regulations, competitive pressures, resource constraints, and shifting societal expectations. Together, these drivers push organizations to adopt proactive sustainability strategies that go beyond compliance and embed environmental objectives into daily operations. This transition from reactive to proactive sustainability management signals a profound shift in how firms address environmental challenges.

Nevertheless, the adoption and implementation of GDCs are not without obstacles. Organizational barriers, including entrenched cultures, limited resources, and capability gaps, particularly constrain small and medium-sized enterprises (SMEs). Many lack the financial and human capital required to build and maintain GDCs. Addressing these barriers demands targeted policy support and organizational commitment to building internal capacity.

Implementation challenges further hinder progress. Firms often struggle with the operational complexity of aligning sustainability with core processes and with the absence of standardized frameworks and metrics for assessing sustainability outcomes. Clear measurement tools are needed to evaluate GDC performance and communicate progress credibly to stakeholders.

The review highlights the critical role of open innovation and ecosystem collaboration in fostering GDCs. Cross-sector partnerships and knowledge-sharing can help firms, especially SMEs, overcome resource limitations and accelerate sustainable innovation. This collaborative orientation represents a departure from traditional closed innovation models and emphasizes the growing relevance of ecosystem-level strategies. Importantly, integrating GDCs into core strategies has been shown to enhance competitive advantage, especially in industries facing stringent environmental regulations and evolving consumer demands. GDCs thus emerge not merely as compliance tools but as drivers of differentiation and long-term value creation.

From a theoretical standpoint, the concept of GDCs invites scholars to revisit the dynamic capabilities framework, incorporating sustainability dimensions more explicitly and linking environmental management theories with strategic management research. Future research should further unpack the micro-foundations of GDCs, including leadership, organizational culture, and individual behaviors that enable sustainable innovation. Additionally, context-specific studies are needed to capture industry and regional variations, recognizing that GDC development is not uniform.

Equally important is the need for robust frameworks that connect GDCs to measurable performance outcomes, integrating both financial and non-financial indicators. Such frameworks would justify investments in sustainability initiatives and demonstrate their tangible benefits.

Practically, firms must embed sustainability in strategic planning and governance, develop capabilities to sense environmental opportunities, seize green innovations, and reconfigure resources effectively. Cross-functional sustainability teams and dedicated

training can support this capability-building. Firms should also collaborate actively with stakeholders across supply chains and policy environments to co-create solutions.

Finally, policymakers play a crucial role in shaping supportive ecosystems for GDCs through incentives, regulatory clarity, and capacity-building programs, especially for SMEs. GDCs signal a paradigm shift in how firms tackle sustainability, transforming it from peripheral concern to strategic core. Fully realizing their potential will require coordinated efforts among academia, industry, and governments to overcome barriers, refine theory, and enable businesses to drive sustainable growth.

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