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Reinforcing green business strategies with Industry 4.0 and governance towards sustainability: Natural-resource-based view and dynamic capability

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Abstract

The study explores the influence of contextual factors surrounding production planning and green strategic investment decision-making practices (GSIDMP) in UK companies. We utilize a mixed-method approach as a research methodology to study the current trend of production planning and GSIDMP. This study's conceptual model is rooted conspicuously in the resource-based theory (RBT), natural-resource-based view, and dynamic capabilities. We empirically examine the nexus among GSIDMP, technological innovation, dynamic capability, and companies' performance. Our study was based on a sample selected from UK-listed companies, FTSE ALL-Share Index for the period (2012–2021). Also, the study utilizes data from the UK Innovation Survey (2018–2020) and corporate disclosure through companies' annual reports as a complementary approach for data collection. Findings of this study explore the interdependencies among company dynamic capability, advanced technological innovation and governance mechanisms, and their mediation influence on the nexus between GSIDMP and companies' performance. This study sheds lights on current business innovation strategies. Findings reveal how current practices of production planning and GSIDM in large UK companies shaped by boardrooms absorptive and adaptive capabilities, knowledge-generating and knowledge-collaboration capabilities, technological adoption, and corporate governance mechanisms. This study offers insight regarding boardrooms proactive engagement in exploration and exploitation activities to strengthen ambidexterity through various innovation trajectories associated with green production and GSIDMP towards sustainability. We provide managerial implications for decision-makers, regulators, investors, scholars, and other stakeholders.

Abbreviations: AR, Annual report; AZ, AstraZeneca; BP, The British Petroleum Company; CDM, Companies dynamic capabilities; CEO, Chief executive officer; CSR, Corporate social responsibility; ESG, Environmental, social and governance; FDI, Foreign direct investment; GSIDMP, Green strategic investment decision-making practices; GVA, Gross value added; IoT, Internet of Things; OECD, The Organization for Economic Co-operation and Development; OLS, Ordinary least squares; ONS, Office for National Statistics; R&D, Research and development; RBT, Resource-based theory; RQ, Research question; RT, Rio Tinto; SDGs, The sustainable development goals; U, Unilever; UK, United Kingdom; UKIS, UK innovation survey.

KEYWORDS
companies performance, dynamic capabilities, ESG performance, governance, green innovation strategies, green production, green strategic investment decisions, natural resource based view, sustainability, sustainable business strategy, technological adoption

1 | INTRODUCTION

Businesses play a pivotal role in dealing with sustainability challenges, yet how businesses tackle these challenges varies widely (Hermelingmeier & von Wirth, 2021). Ambidexterity involves balancing exploration and exploitation to achieve superior performance and enhanced competitiveness (Singh et al., 2022). Companies increase their organizational efforts and resources to develop green products and achieve sustainable development because sustainability practices can improve their performance (Song et al., 2018). Innovation in business strategies and environmental performance is the lifeblood of ecosystems and is crucial for addressing significant global challenges, including climate change. Sustainable business strategies adopt green innovation strategies toward the natural environment and consider the environmental, social, and governance (ESG) pillars through corporate strategic and operational processes. Corporate sustainability reflects a new era of corporate management and control strategies beyond the conventional profit maximization-oriented business model. Prior research on business strategies and the environment has predominantly emphasized business strategies and sustainability, corporate governance, sustainability disclosures, green marketing, environmental management systems, innovation strategies, and environmental policies (Kumar et al., 2021).

Kamble et al. (2020) discussed the findings of current literature on the direct influence of technological adoption on sustainable organizational performance. Industry 4.0 refers to the technological advancement associated with the Fourth Industrial Revolution that fundamentally shifted how global production and supply networks operate through the automation of conventional manufacturing processes and industrial practices, such as large-scale machine-to-machine communication and the Internet of Things (IoT). Industry 4.0 technologies improve communication, self-monitoring, and control mechanisms, while analyzing and diagnosing issues without the need for human intervention. Artificial intelligence including blockchain technology, cloud computing, and big data are key components of business innovation. Business innovation strategies and advanced technological adoption are imperative for companies to manage industry challenges through smart solutions, optimization, mass customization, and smart manufacturing processes (Bag et al., 2021). Technological innovations have accelerated corporate transformation (Bai et al., 2020; Ribeiro-Navarrete et al., 2021) into a new era of production planning and control mechanisms. This includes product and process innovation strategies toward a circular economy and sustainable performance (Alkaraan et al., 2023). Dynamic capabilities enable companies to increase productivity and reduce costs.

Previous studies have examined environmental sustainability from the perspective of dynamic capabilities, facilitating a better understanding of the processes by which companies implement sustainable development strategies (Arranz et al., 2022). Within this paradigm, proactive companies create green innovation strategies by implementing environmental strategies in their green strategic investment decision-making practices (GSIDMP). Based on a systematic literature review combining studies on Industry 4.0, lean manufacturing, and agile manufacturing, Ding et al. (2023) revealed that integrating these elements enhances cost competitiveness, whereas agile manufacturing strengthens flexibility. Other studies focused on linking digital and sustainable transformations to supply chain practices (Jabbour et al., 2020; Lara Schilling & Seuring, 2023) and sustainable development (Bag et al., 2021). Advanced technological adoption strengthens a company's dynamic capabilities across various value creation and capture stages (Climent & Haftor, 2021; Saura et al., 2022). Product innovation management is critical for aligning value creation and capture through the various stages of business model innovation (Sjödin et al., 2020). Advanced technological adoption drives economic and social change, and newly emerging technologies are a pivotal and highly researched domain (Park et al., 2022). Industry 4.0 technologies accelerate business innovation strategies and positively impact environmental development (Gupta et al., 2023; Khan, Chowdhary, et al., 2021).

Efficient innovation strategies require boardrooms to orchestrate their organizational resources efficiently (De Massis et al., 2018). Boardrooms play a critical role in strategic choices; they direct and decide how their internal and external resources are harmonized through GSIDMP. Governments and standard setters promote sustainable green manufacturing processes through GSIDMP toward sustainable performance (Alkaraan et al., 2023). A more recent innovation strategy in the UK was launched in 2021. The guidelines emphasize production planning and control mechanisms associated with GSIDMP through sustainable value creation and the capture toward sustainable organizational performance. The government focuses on innovation through research and development (R&D) intensity to strengthen product-innovation productivity and other innovation trajectories.[1] Companies operate in highly competitive global business environments. To maintain a competitive edge, companies seize opportunities for expansion through new production technologies, product development, the development of existing products, and green raw materials. It has been argued that conventional manufacturing strategies are destructive to the environment, and there is a need for effective governance mechanisms (Yu et al., 2022) to achieve successful GSIDMP outcomes. According to Bloomberg[2] (based on a survey of

[1] https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/timeseries/glbh/gerd
[2] https://sponsored.bloomberg.com/article/mubadala/the-future-of-esg-Investing?sref=eWvCRkRs

800 business decision-makers globally), business leaders believe that no investment can be made without considering ESG issues.

Growing attention to sustainable business strategies has favored the emergence of paradigms aimed at understanding the interdependency between economic and environmental sustainability dimensions (Erbetta et al., 2022). The recent decade has witnessed the emergence of new models of business strategies and environmental research related to boardrooms, green innovation strategies, eco-innovation, and the circular economy, owing to their relevance in improving environmental performance (Kumar et al., 2021). Kumar et al. (2021) recently called for future research on business strategies and the environment to extend the generalizability and impact of prior research endeavors and explore how business strategies that improve environmental performance continue to evolve with agility and creativity to maintain sustainable competitive advantage.

Our study responds to the above call and attempts to fill this gap in the extant literature. Prior research has paid little attention to the influence of contextual factors on business innovation strategies. Mertens et al. (2022) highlighted the link between related disciplines and the call for future research to develop standard views on critical issues central to production planning and control mechanisms, including product innovation trajectories, digital technological adoption, sustainability, and collaboration activities. To the best of our knowledge, the combined impact of technological adoption, companies' dynamic capacities, and governance mechanisms on the nexus between GSIDMP and company performance has not been empirically examined, particularly in large UK companies. Large UK companies contribute 39% of employment and 48% of turnover (House of Commons, 2021). The above discussion emphasizes the importance of exploring the key factors that drive the new era of production planning and GSIDMP in the UK context. This study was guided by the following research question:

> RQ: What are the key factors driving current production planning and GSIDMP in UK companies?

We examine the impact of corporate governance mechanisms, technological adoption, and company dynamics on the relationship between GSIDMP and company performance. In addition, we use the data from the UK Innovation Survey (UKIS) 2021, the main data source for business innovation in the UK companies. This research deliberates on the diffusion of a range of innovation strategies, products, processes, and organizational and marketing innovations. We utilize multi data sets and a mixed methods approach as a research methodology to shed light on the key factors that drive the current practices of production planning and GSIDM. The methodological triangulation incorporates both quantitative and qualitative paradigms. This research strategy offers depth and breadth in interpreting and validating results based on complementary findings (Murphy & Maguire, 2011).

This study's findings contribute to the literature on production planning and green innovation strategies. This study makes the following three contributions. First, the findings offer new evidence from the UK on the essential characteristics of production planning and innovation strategies in various contexts and settings. Second, the findings shed light on the key drivers that reinforce current GSIDMP in large UK companies. Production planning and GSIDMP are shaped by companies' dynamic capabilities, boardrooms' absorptive and adaptive capabilities, knowledge-generating and knowledge-collaboration capabilities, technological adoption, board members' strategic agility, corporate governance mechanisms, and national culture. Third, the conceptual model adopted in this study is rooted in resource-based theory (RBT), natural-resource-based view, and dynamic capabilities. Previous studies have paid little attention to the conceptualization of production planning and GSIDMP based on theory triangulation by amalgamating strong structuration theory and the dynamic capability perspective, particularly the role of board directors (agent-in-focus) in considering the context of emergent structures (agents-in-context).

The remainder of this paper is organized as follows. Section 2 outlines the literature and hypotheses development. Section 3 outlines the theoretical underpinnings and methodology. Section 4 outlines the results, and Section 5 concludes the paper with implications and limitations.

2 | LITERATURE: HYPOTHESES DEVELOPMENT

2.1 | Conceptualization

Understanding sources of sustained competitive advantage has become a major domain of business research (Barney, 2002). Figure 1 depicts the conceptual model grounded on RBT and dynamic capability perspective. The RBT is a widely used perspective for strategic management, operational management, marketing, and supply chain management (Utami & Alamanos, 2023). It focuses on boardrooms effectiveness regarding productive business opportunities through utilizing organizational resources to achieve the required goals. The RBT is appropriate theoretical lenses to predict organizational performance. The theoretical lenses underlying RBT helps exploring how companies maintain competitive advantages to outperform others (Helfat & Peteraf, 2003). The foundation of this theoretical perspective is the heterogeneity of organizational resources and capability, and the assumption of resource immobility. The development of RBT suggests that companies maintain competitive advantage through using the critical assets and building new capabilities through skills acquisition and accumulation of their tangible and intangible assets. According to this theory, resources are valuable and cannot be imitated such as company brand and reputation. These resources include assets, R&D, advanced technology adoption, brand and effective cost management, and knowledgeable management that companies amalgamated to develop existing product/services or to create new product or service to the market (Adner & Helfat, 2003). Organizational external resources include the role of suppliers and customers demand. Organizational capabilities are organizational non-transferable resources that enable companies to improve operational efficiency and productivity, and create, extend, and upgrade their unique resources This include advanced technological adoption

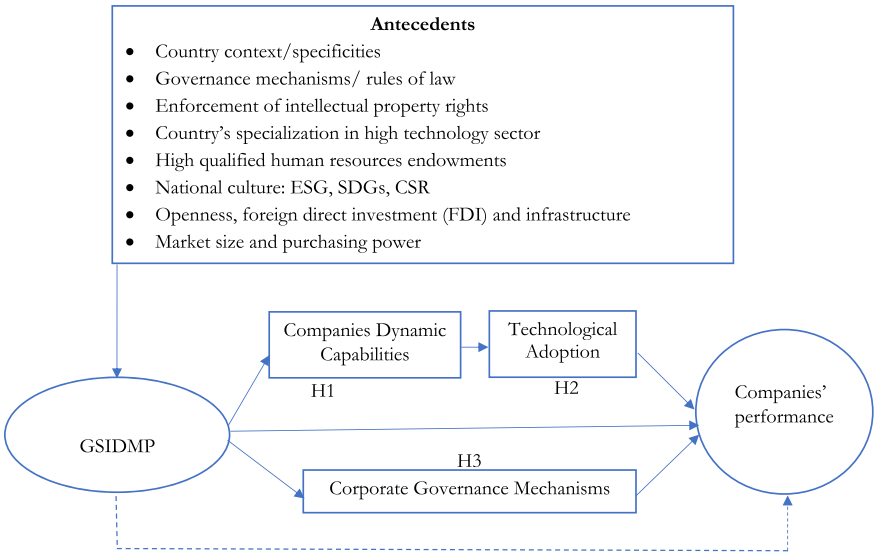


FIGURE 1 The influence of contextual factors on GSIDMP and companies' performance. GSIDMP, green strategic investment decision-making practices.

alliance capability, cooperation, big data deployment, and developing new product. Building on the assumption that strategic resources are heterogeneously distributed between companies and such variations are stable over time, Barney (2002) highlights the association between companies' resources and retained competitive advantages. Companies have competitive advantages through adopting value creation strategies that not concurrently adopted by other competitors. Differentiated products and services create brand and loyalty and can be viewed as sources of competitive advantages. Companies' sources include capabilities such as technological adoption, design, procurement, production and distribution, and services.

Building on the RBT, Hart (1995) proposed a natural resource-based view as perspective of competitive advantages based on the firms' relationships to the natural environment. The natural resource-based view focuses on the connection between environmental challenges and firm resources operationalized through interconnected strategic capabilities: pollution prevention, product stewardship, and sustainable development. The relationship between firm's capabilities and competitive advantages also has been well established in literature. "In the future it appears inevitable that businesses (markets) will be constrained by and dependent upon ecosystems (nature) …. it is likely that strategy and comitative advantage in the coming years will be rooted in capabilities that facilitate environment sustainable economic activity- a natural-resource-based view of the firm" (Hart, 1995, p.991). Environmental business practices such as pollution reduction and waste management are associated through all stages of GSIDMP. Green production innovation will take into consideration reducing the impact on the environment, uses less resources, and prevent waste generation and has significant impact on companies' environmental performance (Singh et al., 2020). The study of Andersén (2021) indicates that green production innovation influences differentiation advantages and such relationship strengthened by having green suppliers. The natural resource-based view focuses on how companies can use resources or develop resources to achieve financial and environmental performance (Hart & Dowell, 2010). Dynamic capabilities enable companies to respond to the internal and external environment and improve companies' performance (Nickerson & Zenger, 2004). Dynamic capability refers to company ability to integrate, develop, and reconfigure internal and external competencies to respond the highly changing environment (Teece et al., 1997) including strategic renewal (Agarwal & Helfat, 2009).

Successful innovation strategies depend on companies' capabilities to sense and seize opportunities for organizational growth (Helfat & Martin, 2015; Teece, 2012). Maintaining competitive advantage is the outcome of integrating positions achieved over time and organizational processes (Teece et al., 1997). This perspective emphasizes the role of companies in reshaping and reconfiguring their capabilities and resources to cope with changing market environments and technologies. Successful innovation strategies depend on companies' capabilities to sense and seize opportunities for organizational growth (Helfat & Martin, 2015; Teece, 2012). Dynamic capabilities are critical determinants of effective green production planning and successful GSIDMP. Teece et al. (1997) argued that maintaining a competitive advantage is the outcome of integrating positions achieved over time and organizational processes. This perspective emphasizes the role of companies in reshaping and reconfiguring their capabilities and resources to cope with changing market environments and technologies. Teece (2007) viewed dynamic capability as sensing, seizing, and configuring organizational resources, including exploring and collecting information and learning about markets, customers, competitors, and other external factors related to organizational activities. Teece (2017) articulated three pillars of dynamic capability: (i) sensing, scanning, and screening opportunities and threats; (ii) seizing opportunities through selecting the best available option possible, making investments, and leading organizational resources; and (iii) reconfiguring and transforming organizational resources accordingly. Teece (2007, 2009) redefined the concept of dynamic capability as capabilities that enable companies to create and protect their intangible assets to maintain long-term superior organizational performance. Agarwal and Helfat (2009) highlighted the importance of dynamic capabilities in strategic organizational renewal.

Absorptive capabilities emphasize boardrooms' capabilities to search for and use external information to support strategic choices through production planning and GSIDMP. However, absorptive capabilities require boardrooms to absorb knowledge of the legal and regulatory environment, including customer needs and behaviors, and products/services can be customized to fit customers' changing needs. Absorptive capability emphasizes critical knowledge acquisition, integration, and utilization (Zahra & George, 2002). Adaptive capability refers to a company's ability to quickly configure organizational activities to respond to changing demands and achieve competitive advantage (Dixon et al., 2014). Knowledge-generating capabilities refer to a company's capability to redefine, reuse, redesign, restructure, and develop activities that facilitate the generation of new knowledge, such as R&D. Knowledge collaboration activities are key components enabling companies to gain and exchange resources and engage in shared goals through formal and informal structures. Dynamic capabilities are the building blocks of successful business innovation strategies and can be viewed as integral elements of organizational structure, systems, and organizational resources (Teece, 2018).

2.2 | Backing GSIDMP with technological adoption, dynamic capability, and governance toward sustainability

The strategic business environment is changing faster than ever because of the radical innovation trajectories embedded in new product development and new markets. The traditional linear economy has been widely criticized because neither companies nor consumers consider the consequences of a product's ecological impact throughout its life cycle, resulting in resource waste and environmental pollution. Sustainable business models emphasize sustainable value creation by seizing growth opportunities and mitigating the risks associated with economic, environmental, and social development. Business innovation strategies associated with GSIDMP incorporate various innovation trajectories, including product, process, and organizational innovation. Green strategic investment decisions require significant long-term capital expenditure and have a long-term impact on company performance. Such strategic decisions are rooted in decision-makers' knowledge, know-how, and years of industry experience, profoundly impacting the reinforcement of production, planning, and control (Alkaraan & Northcott, 2006, 2013). Eco-innovation and eco-design are among the most important strategies for manufacturing innovation. Eco-design responds to the development of new, environmentally friendly technologies, products, and services. Eco-innovation strengthens production process efficiency by transforming operational manufacturing processes to reduce resource consumption. Successful green production planning and GSIDMP create commercialization opportunities through new product development, services, and markets. Previous literature contains various research mainstreams on business innovation strategies in different contexts and settings using specific quantitative and qualitative research paradigms, country surveys, and case studies in different contexts and settings (see Brunswicker & Chesbrough, 2018; Chesbrough, 2017; Chesbrough & Bogers, 2014; Lee & Miozzo, 2019; Madaleno et al., 2020; Radicic & Alkaraan, 2022). Advanced technological adoption leverages companies' dynamic capabilities through improved data, while dynamic manufacturing capabilities enable companies to amalgamate sustainable manufacturing processes. Technological transformation makes flexibility in operational remanufacturing processes critical to manufacturing innovation performance (Bag et al., 2021). However, this transformation is influenced by dynamic capabilities and involves substantial investments in advanced technologies (García-S'anchez et al., 2021). In addition to company size and level of experience, R&D expenditure, and intensity are key indicators of dynamic capability because they measure investments in searching for new technological solutions or other innovation trajectories. R&D and other innovation-related trajectories increase the probability of companies modifying their resource bases through new products, whereas conventional investment levels cannot capture companies' abilities regarding investment effectiveness Laaksonen and Peltoniemi (2018).

Prior studies provide evidence of the effects of collaborative activities on organizational performance in various industry sectors, including biotechnology (Powell et al., 1996), semiconductors, steel (Rowley et al., 2000), and technology (Shubbak, 2018). Zheng et al. (2011) viewed the concept underlying dynamic capabilities as a company's ability to acquire, create, and integrate knowledge resources to sense and respond to environmental dynamics. They revealed that all companies may develop their dynamic capabilities, although their dynamic capabilities can be unique, leading to different organizational performance. However, the relationship between a company's dynamic capabilities and performance has not been clearly explored. Companies in developing countries invest in various innovation trajectories including R&D, human scientific capital, and collaboration with universities and other research institutions (Hervas-Oliver et al., 2021). Drawing on a survey of the UK and the United States, Lee and Miozzo (2019) revealed that science-based companies, such as science-based manufacturing companies, are active collaborators within universities regarding various types of innovation. I4.0 technologies help capture data from the manufacturing process (resource consumption rate and productivity) using the Internet of Things (IoT) for production and value chain optimization (Bag et al., 2021). The environmental benefits of eco-innovation include the use of clean technology and reductions in water, electricity, gas, and petrol consumption during production. Furthermore, eco-design innovation leverages a company's profit growth (Yu et al., 2021). Green product planning and GSIDMP help companies rebuild trust and legitimacy, meet public expectations, and establish solid credentials. Manufacturing innovation strategies using innovative eco-design trajectories can improve financial performance (Soh & Wong, 2021; Yu et al., 2021). Parrilli et al. (2020) examined how regional context and technological capabilities affect innovation outputs. Technological adoption enables companies to cope with highly competitive business environments and meet changing customer needs. Technological adoption strengthens decision-making processes (Benitez et al., 2020; Culot et al., 2020; Meindl et al., 2021). Companies increase their

organizational efforts and resources to develop green products and achieve sustainable development because sustainability practices can improve their performance (Song et al., 2018). However, little attention has been directed toward empirically examining the interdependency among technological adoption, dynamic capability, GSIDMP, and company performance. Thus, we developed the following hypotheses:

H1. A company's dynamic capability mediates the relationship between GSIDM and company performance.

H2. Technological adoption mediates the nexus between GSIDM and strengthens companies' performance.

2.3 | The influence of corporate governance

Corporate governance mechanisms influence strategic boardroom decisions including production planning. Corporate governance has shifted from conventional paradigms focusing on agency costs to ethical leadership and decision-making paradigms focusing on ESG and corporate sustainability. Investors, regulators, policymakers, and stakeholders seek company disclosures beyond conventional financial information. The UK corporate governance codes (2016, 2018) require companies' boardrooms to report their activities, business strategies, and commitment to sustainable value creation and performance associated with their GSIDMP. Companies' reporting practices of financial and non-financial disclosures must maintain completeness, relevance, and reliability and allow effective communication mechanisms with stakeholders. Companies' ESG performance reflects their commitment to environmental climate change governance and sustainable performance. Recent studies (Alkaraan et al., 2022; Hussainey et al., 2022) found that business model transformation disclosures correlate with companies' financial performance. The effective integration of ESG pillars through strategic boardroom decisions and GSIDMP is a significant matter of boardroom commitment to stakeholders. Board commitment to sustainable performance materializes by balancing social, ecological, and financial returns. Prior research has examined the relationship between corporate governance and company performance. Harjoto et al. (2019) drew on a sample of US firms to examine how board nationality diversity and educational background reveal how improving diversity enhances companies' social performance. Recent studies have illustrated how companies' technological, economic, ecological, and social performance are influenced by boardrooms practices (see Alkaraan et al., 2022; Hussainey et al., 2022; Nadeem et al., 2020; Nahum & Carmeli, 2020). Accordingly, it is important to examine the interdependence among corporate governance mechanisms, GSIDM, and company performance. Thus, we postulated the following hypothesis:

H3. Corporate governance mechanisms mediate the relationship between GSIDMP and companies' performance.

3 | RESEARCH METHODOLOGY

This study employed a mixed-methods research approach using quantitative and qualitative data collection methods. Triangulation research methodologies helped in interpreting the findings (Edwards et al., 2020; Tashakkori & Newman, 2010).

3.1 | Data collection method

We used data triangulation to answer the research question underpinning this study and enhance the validity and credibility of the interpretation of the findings. Data triangulation helped the authors offer a holistic perspective on the contextual factors influencing GSIDMP and company performance. We adopted the following multiple datasets.

We used data selected from the UK Innovation Survey (UKIS) 2021, which is the main data source for business innovation in UK companies. This source offers a comprehensive view of the current practices of business innovation strategies and sheds light on the current trends in business innovation strategies, as the survey was based on a sample of 31,928 UK companies. The UKIS 2021 asked companies for information on their innovation activities over a 3-year period (2018–2020). The UKIS 2021 is the twelfth of its kind, and this survey has been conducted every 2 years since 2005. It is the primary data source for business innovation in the UK. conducted by the Office for National Statistics (ONS). Innovation is considered a significant improvement in goods and services. These innovation trajectories may be novel for businesses and markets. New business practices are relevant to supply chain management, business restructuring, knowledge management, lean production, and quality management. Where appropriate, this study compared the results with those from 2008 to 2010, as the first survey was conducted using a sample based on the UK Standard Industrial Classification (SIC, 2007). The UK concept of innovation is based on the Organization for Economic Co-operation and Development (OECD) definition as articulated in the Oslo Manual (2018).[3]

1. "The introduction of a new or significantly improved product or process."
2. "Engagement in innovations project not yet complete, scaled back, or abandoned."
3. "New and significantly improved organizational forms, business structures or practices, and marketing concepts or strategies."
4. "Investment activities include internal R&D, training, acquisition of external knowledge or machinery and equipment linked to innovation activities."

Businesses that engage in any of the innovation activities from 1 to 3 are considered innovative. Businesses engaged in any of activities from 1 to 4 are considered broadly innovative. Businesses that engage in the activities mentioned in the third statement are classified as wider innovators.

[3] https://www.oecd.org/science/oslo-manual-2018-9789264304604-en.htm

The empirical analysis underlying this study is based on a sample selected from UK listed companies, the FTSE ALL-Share Index for 2012–2021. Our initial sample comprised a 1960 firm-year observation. This study developed a disclosure index for technological adoption based on narrative sections from annual reports of UK companies. It leveraged computer-aided textual analysis, a widely evolved domain, to identify, examine, and analyze the various linguistic features of the document (Loughran & McDonald, 2011). To strengthen the debate and interpret the results, we used extracts from narrative disclosures selected from large UK companies.

3.2 | Empirical analysis

The study used a regression model to examine the three hypotheses underpinning the definition of the variables, as shown in Table 1. All regression models incorporated year and industry fixed effects. We used descriptive statistics to examine the relationships between GSIDMP technology adoption, governance mechanisms, and company performance. To test the proposed hypotheses, we ran the modules following the models using ordinary least squares (OLS). To reduce the standard error and avoid the effect of omitted variable bias, we reran our regressions using fixed-effects and random-effects panel models.

$$PERF = \alpha_0 + \beta_1 GSIDMP_{it} + \beta_1 GSIDMP_{it} \text{xTADPT} + \sum_{i=1}^{n} \beta_i CONTROLS_{it} + \varepsilon_{it} \quad (1)$$

$$PERF = \alpha_0 + \beta_1 \text{CDC}_{it} + \beta_1 \text{CDC}_{it} \text{xTADPT} + \sum_{i=1}^{n} \beta_i CONTROLS_{it} + \varepsilon_{it} \quad (2)$$

$$PERF = \alpha_0 + \beta_1 \text{GOV}_{it} + \beta_1 \text{GOV}_{it} \text{xTADPT} + \sum_{i=1}^{n} \beta_i CONTROLS_{it} + \varepsilon_{it} \quad (3)$$

Furthermore, the method uses narrative extracts from corporate disclosures using companies' annual reports to provide content regarding the influence of technological adoption, companies' dynamic

TABLE 1 Variable definitions.

Variables	Symbols	Definitions
Green strategic investment decision-making practices	GSIDMP	Principal components to reduce the number of variables and to learn about the underlying structure of firm dynamic capability based on set of non-current intangible assets.
Technological adoption	TADPT	Percentage of technological adoption disclosure using a comprehensive dictionary based on wordlist (bag of words) designed to capture as many different words as possible relating to the industry 4 and technological adoption
Companies' dynamic capabilities	CDC	Principal components to reduce the number of variables and to learn about the underlying structure of firm dynamic capability based on set of non-current tangible and intangible assets including R&D and R&D intensity patents)
Governance mechanisms	GOV	Principal components to reduce the number of variables and to learn about the underlying structure of firm dynamic capability based on set of governance mechanism variables including ESG score-board experience-board size-board independents-audit committee independent.
Firm performance	PERF	Principal components to reduce the number of variables and to learn about the underlying structure of firm dynamic capability based on set of profitability measures.
Firm size	FSIZE	Natural log of total assets of the company.
Return on equity	ROE	Is the measure of a company's net income divided by its shareholders' equity.
Audit committee size	Audit com size	The number of directors on the audit committee board.
Audit committee independence	Audit com ind	The percentage of independent directors on the audit committee board
Audit committee expertise	Audit com exp	The level of accounting expertise on the audit committee.
Board size	BSIZE	The number of directors on the board of directors.
Board independence	BIND	The percentage of independent directors on the board of directors.
Board expertise	BEXP	The level of accounting expertise on the board of directors.
Sales to assets	STA	The standard deviation of sales/total asset over the last six fiscal year
Idiosyncratic stock volatility	BETA	The slope of the 52-week regression line of percentage price change of the stock relative to its benchmark
Market capitalization	MCAP	The total value of all a company's shares of stock. It is calculated by multiplying the price of a stock by its total number of outstanding shares.
Return on assets	ROA	Measure of profitability (EBIT ÷ assets)
Financial leverage	LEV	Long-term debt/total assets

capabilities, and governance mechanisms (ESG and board composition) on GSIDMP and company performance. The rationale for using narrative extracts from companies' annual reports is to provide depth and breadth by interpreting the results as a complementary research paradigm to validate the results.

4 | RESULTS AND DISCUSSION

4.1 | Current innovation strategies in large UK firms

Figure 2 shows the percentage of large UK firms engaging in various implementations of GSIDMP toward innovation strategies over 3 years (2018–2020). This study is based on four main innovation trajectories: (i) organizational innovation, (ii) product innovation, (iii) process innovation, and (iv) marketing innovation.

Figure 2 illustrates the various innovation strategies embedded in GSIDMP. As shown in Figure 1, broader innovation ranked as the top priority for 60% of UK companies. Over the decade 2010–2020, over 50% of large UK companies were innovation active, 44% were broader innovators, and 35% were wider innovators. Furthermore, innovation investment activities focusing on product and process innovation increased over the period 2018–2020, as shown in Figure 2.

Firms' dynamic capabilities have a significant impact on GSIDMP. Technological adoption enables boardrooms to improve productivity and address their commitment toward sustainability through intense R&D investment. Successful GSIDMP requirements include industry sector experience, operating cashflows, and partnerships with suppliers, customers, and other stakeholders across a sustainable value chain.

> "We continued to provide oversight of the effectiveness of key engineering and technology processes and operations, including the delivery of major product development and technology programmes." (RR, AR, 2021, p.106)

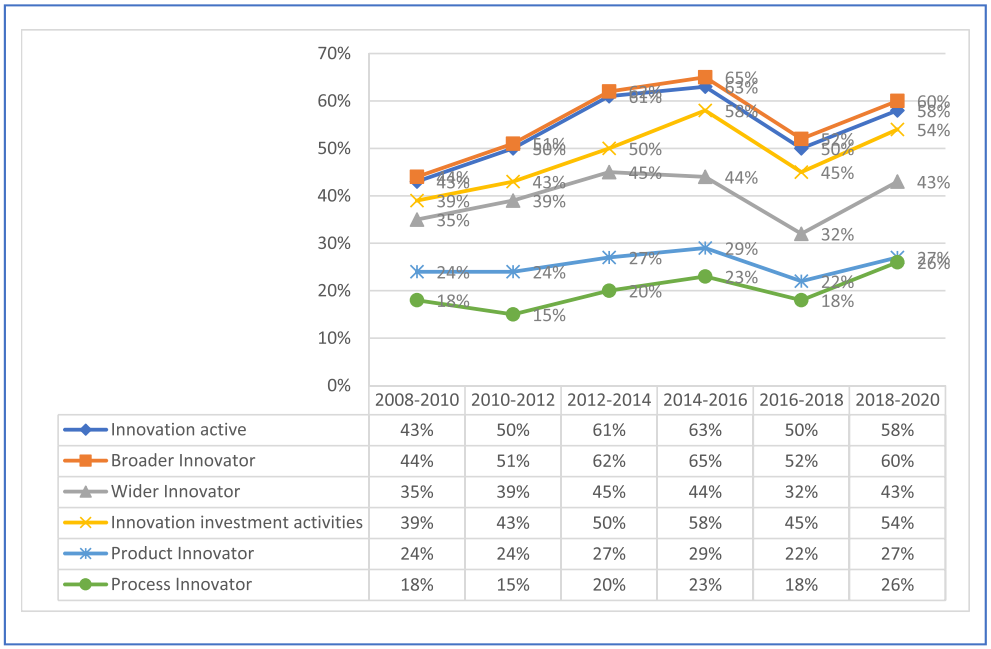
> "We will look for new options and innovative ways of bringing projects on stream faster, but we will only do this in line with our ESG standards." (CEO, RT, AR, 2021, p.13)

> "… Our new digital hub in Pune, India, is designed to create, grow and deliver a range of digital solutions to support new and emerging business models … We will use the hub to partner and collaborate with other leading institutions …." (BP, AR, 2021, p.14)

Powell et al. (1996, p.116) concluded that "when the knowledge base of an industry is both complex and expanding, and the sources of expertise are widely dispersed, the locus of innovation will be found in networks of learning, rather than in individual firms." These companies can acquire substantial technological knowledge by regularly scanning and screening information from various sources, as revealed by the following narrative extracts from annual reports.

> "Investing to create long-term growth and sustainable value technology is the lifeblood of our business …" (CEO, RR, AR, 2021, p.7)

> "We innovate with a strong focus on digital to drive operational efficiencies, empower our workforce, and engage better with our customers." (BP, AR, 2021, p.14)



	2008-2010	2010-2012	2012-2014	2014-2016	2016-2018	2018-2020
Innovation active	43%	50%	61%	63%	50%	58%
Broader Innovator	44%	51%	62%	65%	52%	60%
Wider Innovator	35%	39%	45%	44%	32%	43%
Innovation investment activities	39%	43%	50%	58%	45%	54%
Product Innovator	24%	24%	27%	29%	22%	27%
Process Innovator	18%	15%	20%	23%	18%	26%

FIGURE 2 Percentage of large UK companies engaging in innovation activities (2008–2020).

> "We have already made considerable progress on the testing of sustainable fuels and the development of new products and engine architectures." (CEO, RR, AR, 2021, p.8)

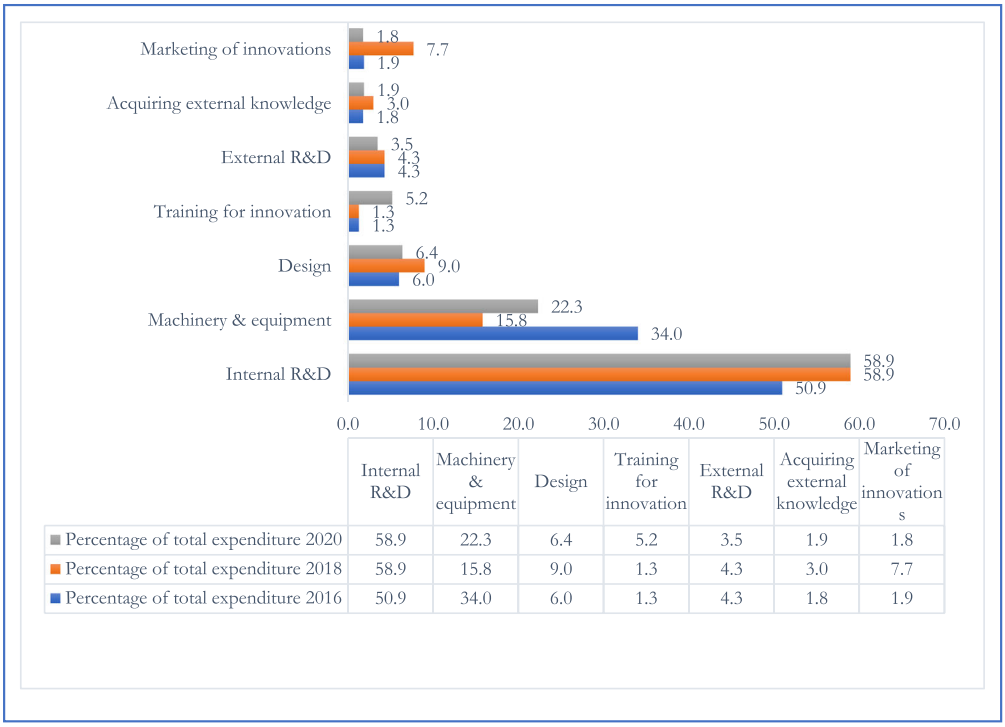
Figure 3 shows that GSIDMP related to R&D investment (internal and external) was the top priority for UK companies over the period 2016–2020. As revealed by previous research (e.g., Alam et al., 2020), the intensity of R&D investment does not create a return throughout the same year; instead, the current year's investment in R&D reduces profit for the year. However, R&D investment improves future organizational performance. R&D investment is an essential determinant of sustainable value creation and performance. Open innovation is a framework that leverages internal R&D through external knowledge to enhance the current business model. This enables new internal R&D to be shared externally for use in other business models. The term open innovation refers to a situation where an organization does not only rely on its own internal knowledge, sources, and resources (such as its own staff or R&D) for innovation (of products, services, business models, processes, etc.) but also uses multiple external sources (such as customer feedback, published patents, competitors, external agencies, and the public) to drive innovation (Chesbrough & Bogers, 2014, p.17). However, after the financial crisis, some organizations employed the language of Open Innovation to reduce or eliminate internal R&D and relied on outsourcing instead" (Chesbrough, 2020, p.2). Large UK companies invest primarily in internal and external R&D activities to leverage organizational performance. This is shown in Figure 3. Internal and external R&D account for 59.9% and 3.5%, respectively, representing a high percentage of investment expenditures in innovation. GSIDMP draws on companies' dynamic capabilities, amalgamated by the intensity of internal R&D and other types of strategic investment projects in both tangible and intangible assets, including external R&D, skilled human capital, collaboration with universities, and other national and international research centers, as revealed by the following extract from the company's annual reports:

> "We estimate that we will invest approximately $7.5 billion in the capital between 2022 and 2030 to deliver our decarbonization strategy (approximately $1.5 billion over the period 2022 to 2024." (RT, AR, 2021 p.81)

> "Innovate by investing in science, platforms, and capabilities, including using AZ technologies and research capabilities." (AZ, AR, 2021, p.25)

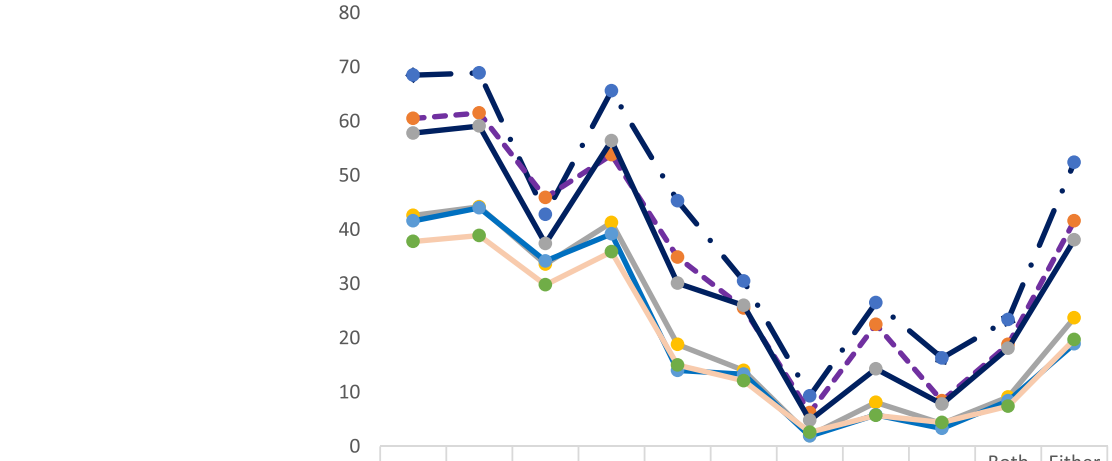
> "Our marketing and R&D teams use these insights plus the best ideas and thinking from specialists outside Unilever to develop our brands and products. We spent €847 million on R&D in 2021." (U, AR, 2021, p.12)

> "We partner with Alibaba across 13 markets. In China, our collaboration goes beyond core commerce into digital transformation across the value chain: from suppliers to marketing to consumer recycling. In March 2021, we launched a joint innovation centre in Hangzhou, China, to quickly test, refine, and scale product innovations. Our strategic partnership with Alibaba's Lazada platform has helped our products reach consumers across South East Asia since 2017." (U, AR, 2021, p.26)



	Internal R&D	Machinery & equipment	Design	Training for innovation	External R&D	Acquiring external knowledge	Marketing of innovations
Percentage of total expenditure 2020	58.9	22.3	6.4	5.2	3.5	1.9	1.8
Percentage of total expenditure 2018	58.9	15.8	9.0	1.3	4.3	3.0	7.7
Percentage of total expenditure 2016	50.9	34.0	6.0	1.3	4.3	1.8	1.9

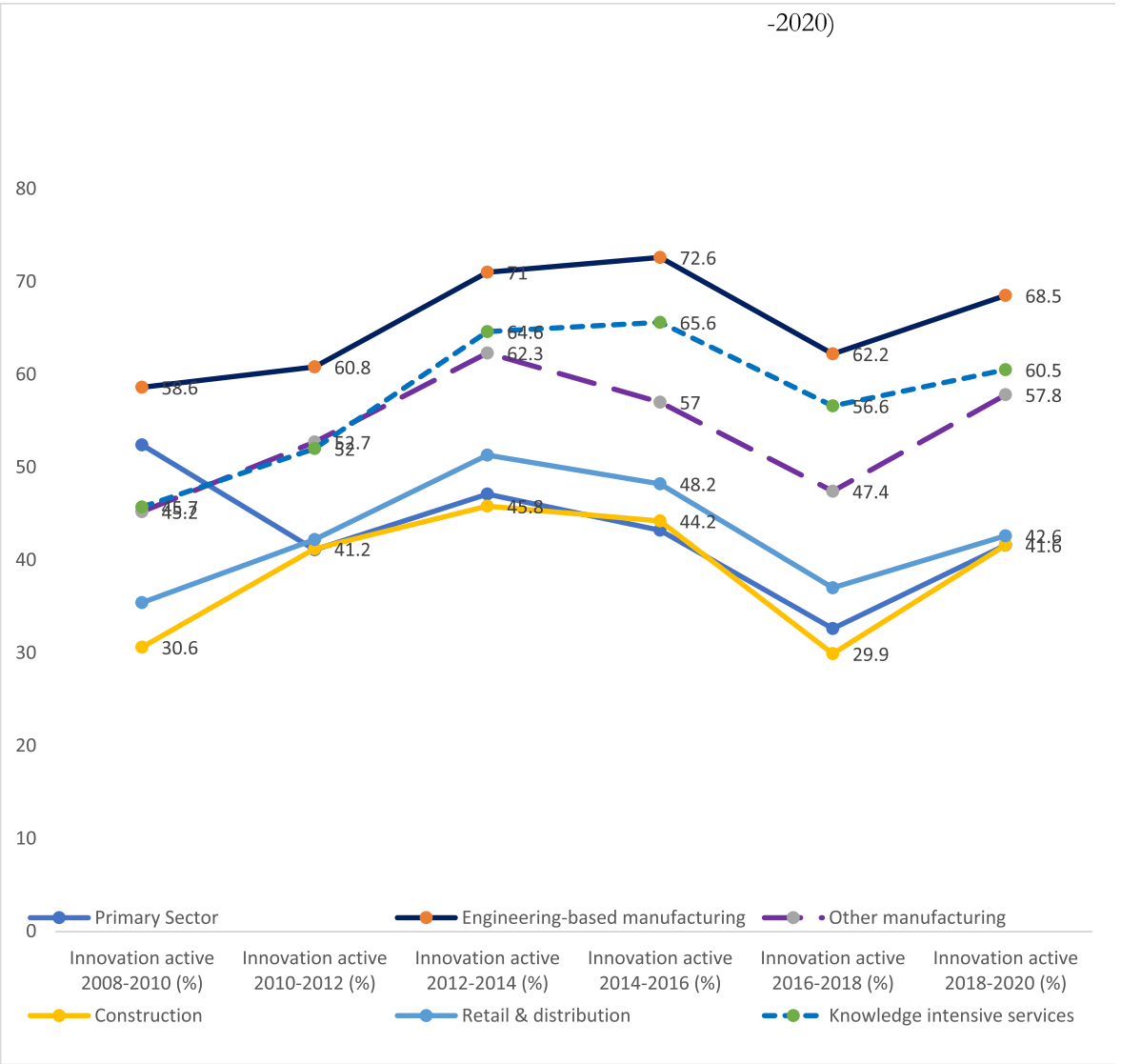
FIGURE 3 GSIDMP-percentage of companies' innovation investment expenditure over the period 2016–2020. GSIDMP, green strategic investment decision-making practices.



	Innovation active (%)	Broader innovator (%)	Wider innovator (%)	Undertaking innovation activities (%)	Product innovator (%)	Process innovator (%)	Abandoned activities (%)	On-going activities (%)	Scaled back (%)	Both product AND process innovator (%)	Either product OR process innovator (%)
Engineering-based manufacturing	68.5	68.9	42.8	65.6	45.3	30.5	9.3	26.5	16.3	23.4	52.4
Knowledge intensive services	60.5	61.5	45.9	53.8	34.9	25.5	6.2	22.5	8.4	18.8	41.6
Other manufacturing	57.8	59.1	37.4	56.4	30.1	26	4.8	14.3	7.8	18.1	38.1
Retail & distribution	42.6	44.2	33.6	41.3	18.8	14	2	8.1	4.2	9.1	23.7
Construction	41.6	44	34.2	39.2	14	13.3	1.9	5.8	3.3	8.4	18.9
Other services	37.8	38.9	29.8	35.9	15	12.1	2.6	5.7	4.4	7.4	19.7

	Innovation active (%)	Broader innovator (%)	Wider innovator (%)	Undertaking innovation activities (%)	Product innovator (%)	Process innovator (%)	Abandoned activities (%)	On-going activities (%)	Scaled back (%)	Both product AND process innovator (%)	Either product OR process innovator (%)
Primary Sector	41.6	43.0	29.3	37.9	12.8	14.6	1.5	11.2	4.7	5.8	21.6
Engineering-based manufacturing	68.5	68.9	42.8	65.6	45.3	30.5	9.3	26.5	16.3	23.4	52.4
Other manufacturing	57.8	59.1	37.4	56.4	30.1	26.0	4.8	14.3	7.8	18.1	38.1
Construction	41.6	44.0	34.2	39.2	14.0	13.3	1.9	5.8	3.3	8.4	18.9
Retail & distribution	42.6	44.2	33.6	41.3	18.8	14.0	2.0	8.1	4.2	9.1	23.7
Knowledge intensive services	60.5	61.5	45.9	53.8	34.9	25.5	6.2	22.5	8.4	18.8	41.6
Other services	37.8	38.9	29.8	35.9	15.0	12.1	2.6	5.7	4.4	7.4	19.7

FIGURE 4 Innovation strategies by sector (2018 to 2020).



	Innovation active 2008-2010 (%)	Innovation active 2010-2012 (%)	Innovation active 2012-2014 (%)	Innovation active 2014-2016 (%)	Innovation active 2016-2018 (%)	Innovation active 2018-2020 (%)
Primary Sector	52.4	41.1	47.1	43.2	32.6	41.6
Engineering-based manufacturing	58.6	60.8	71.0	72.6	62.2	68.5
Other manufacturing	45.2	52.7	62.3	57.0	47.4	57.8
Construction	30.6	41.2	45.8	44.2	29.9	41.6
Retail & distribution	35.4	42.2	51.3	48.2	37.0	42.6
Knowledge intensive services	45.7	52.0	64.6	65.6	56.6	60.5
Other services	31.5	40.3	48.6	42.6	30.7	37.8

FIGURE 5 Innovation active companies by sector (2008–2020).

"We have over 20,000 patents protecting the ideas, discoveries, and breakthroughs that our global team of 5,000 world-leading experts produce. We invest around €1 billion in R&D each year." (U, AR, 2021, p.192)

GSIDMP is a transformational process that replaces conventional manufacturing processes. Innovation strategies in UK companies are rooted in a strong economy, advanced manufacturing companies, and strong specialization in chemicals, semiconductors, and software

(Parrilli & Radicic, 2021). Industrial manufacturing companies primarily derive various innovation strategies, engineering-based manufacturing companies, and knowledge-intensive service companies, as shown in Figures 4 and 5. These companies continue to maintain their positions as the largest active innovative companies from 2008 to 2020, as shown in Figure 4.

> "We have engineering excellence at our heart and an incredible focus on innovation, research, and development activity that creates opportunities for significant value creation." (RR, Chair, 2021, p.5)

Innovation strategies require resources and a combination of adaptive and absorptive capabilities (Hervas-Oliver et al., 2021) for competitive advantage (Radicic, 2020). Customer loyalty and the demand for customizing and optimizing products and processes have become more pronounced (Kumar et al., 2021). To remain competitive, companies must rely on collaborative and partnership activities through their GSIDMP.

Collaborative activities leverage companies' dynamic capabilities to significantly impact product and process innovation. Boardrooms contribute to GSIDMP through strategy formulation and control because of their responsibility and accountability regarding the outcomes of their GSIDMP and strategic choices. Effective boardrooms govern GSIDMP and engage with stakeholders, including their partners and employees (Klarner et al., 2021).

> "With the low-carbon transition at the heart of our strategy, we will continue to focus our exploration efforts on commodities essential for the energy transition. We also evaluate emerging opportunities in the circular economy and green energy production." (RT, AR, 2021 p.17)

> "Develop products and technologies that help our customers decarbonize … We are working closely with our customers and others to develop more secure and sustainable value chains and accelerate the development of cleaner production pathways for our products … We will strive to align our business priorities with society's expectations and ensure sustainability considerations are at the core of every decision we make." (RT, AR, 2021, p.13)

> "In 2022, we will focus on delivering the strategy in collaboration with our partners and other stakeholders." (Chairman, RT, AR, p.7)

> "By leveraging relationships and building new partnerships, we aim to provide integrated energy and mobility solutions to help cities and industries reduce carbon emissions while creating exciting business opportunities." (BP, AR, 2021, p.14)

> "Collaborative efforts also led to the advancement of repair and refurbishment capabilities for bearings that reduce the demand for spare parts by around 90%. This supports our sustainability goals by increasing the circular economy." (RR, AR, 2021, p.46)

> "Our ability to create value is underpinned by the quality of our assets, the capabilities of our people, our operational and sustainability performance, innovative partnerships, and disciplined capital allocation." (RT, AR, 2021, p.23)

> "We work in partnership with a growing network of stakeholders – governments, communities, customers, and suppliers – who help expand our understanding, capabilities, and, ultimately, our ability to be the best operator and a responsible steward of resources" (RT, AR, p.23).

The UK manufacturing sector employs 2.7 million, representing 69% of business R&D, contributes 11% of gross value added (GVA), and accounts for 45% of total exports.[4] Radical innovation in UK companies can be viewed as a transformative domain, challenging industry norms and replacing existing processes and technology toward value-creating and sustainable performance.

> "We will advance projects like Rincon and Simandou, and at Oyu Tolgoi we expect to reach sustainable production in the first quarter of the year." (CEO, RT, AR, 2021, p.9)

> "Materials used in products today may not be the preferred choice in the future if they cannot establish their environmental, social, and governance (ESG) credentials or develop strong circular solutions." (RT, AR, 2021, p.107)

> "We have stepped up our investments in science and technology to strengthen the quality and efficacy of our products … Focusing our R&D activities on fewer and bigger projects also brings innovations to market faster. In total, our innovation programme helped to deliver €1 billion in incremental turnover in 2021 – double that of 2020." (CEO, U, AR, 2021, p.15)

4.2 | The mediating effects of technology adoption, CDC, and governance mechanisms on GSIDMP and companies' performance

Table 2 presents the descriptive statistics and correlation matrix of the research variables underlying the empirical model. The mean value

[4]Office of National Statistics

TABLE 2 Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
Performance	1960	19	18.21	−18	42.76
GSIDMP	1960	8.201	15.091	−85.15	269.11
CDC	1960	5371.341	36668.158	0	772,000
Technology adoption	1960	98553.863	97810.971	0	615,947
Governance	1960	12.99	16.143	0	28

Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)
(1) ROA	1.000				
(2) GSIDMP	0.014	1.000			
	(0.647)				
(3) Technological adoption	0.085	0.043	1.000		
	(0.000)	(0.353)			
(4) CDC	0.138	0.316	0.458	1.000	
	(0.000)	(0.000)	(0.000)		
(5) Governance mechanism	0.085	0.043	1.000	0.458	1.000
	(0.000)	(0.353)	(0.000)	(0.000)	

Note: CDC, companies' dynamic capabilities; GSIDMP, green strategic investment decision-making practices; ROA, return on asset.

of company performance was 19, and the minimum and maximum values were 18 and 42.76, respectively, as shown in Table 2. The mean value of companies' dynamic capabilities was 5371, whereas the maximum value was 772,000. The mean value of technological adoption was 98,553, representing the average frequency of words related to technological adoption disclosed in the companies' annual reports. The mean value of the governance indicator was 12.99. This indicates that most of the companies included in our sample positively affect governance mechanisms and financial performance.

i. The influence of technological adoption on GSIDMP and companies' performance

The results revealed a positive relationship between technological adoption, GSIDMP, and companies' financial performance. Technological adoption mediates the relationship between companies' GSIDMP and financial performance, as Table 3 shows.

> "We continued to invest prudently in the new technologies, products, and services our customers will need for their future success and saw our more recent investments deliver new growth opportunities." (CEO, RR, AR, 2021, p.6)

ii. The influence of companies' dynamic capabilities on GSIDMP and companies' performance

The regression analysis results revealed a positive relationship between companies' dynamic capabilities, GSIDMP, and performance, as shown in Table 4.

> "Our priorities reflect how we are working to deliver our growth through innovation strategy and achieve our purpose of pushing the boundaries of science to deliver life-changing medicines. Global R&D centers Cambridge (UK), Gaithersburg, MD (US), Gothenburg, Sweden, and other R&D centers and offices; South San Francisco, CA, US New York, NY, US, New Haven, CT, US Boston, MA, US, Alderley Park and Macclesfield, UK, Shanghai, China, Osaka, Japan." (AZ, AR, 2021, p.2)

> "Our supplier ecosystem includes millions of people worldwide – from large multinationals to start-ups and small local producers who provide us with goods and services such as raw materials, logistics, advertising, professional services, and much more. We also work with various business partners, including industry peers, innovation agencies, universities and joint ventures, to help unlock growth and find solutions that benefit our stakeholders." (CBO, U AR, 2021, p.27)

> "We are seizing strategic growth opportunities for our established products … The new facilities feature advanced manufacturing equipment on a smaller but more efficient footprint, including digital engineering and robotics capabilities …" (RR, AR, 2021, p.29)

iii. Influence of governance mechanisms on GSIDMP and companies' performance

TABLE 3 Technology adoption, GSIDMP, and companies' performance.

Variables	OLS performance	Fixed performance	Random performance
GSIDMP	5.4208*	5.1121*	5.0065*
	(8.9908)	(6.772)	(6.665)
Technological adoption	1.5705**	1.7405**	1.7405**
	(4.7706)	(4.9906)	(4.9906)
c. GSIDMP#c.Technological adoption	9.872***	10.25***	10.25***
	(0.659)	(0.697)	(0.697)
Constant	12.02*	8.17*	8.725*
	(0.123)	(0.254)	(0.176)
No observations	1940	1940	1940
R-squared	0.320	0.280	0.275

Note: Standard errors in parentheses. GSIDMP, green strategic investment decision-making practices; OLS, ordinary least squares.
***$p < .01$, **$p < .05$, and *$p < .1$.

TABLE 4 GSIDM, CDC, and companies' performance.

Variables	OLS Performance	Fixed performance	Random performance
GSIDMP	1.5908	4.2508*	3.2804**
	(1.4708)	(1.4208)	(1.3408)
CDC	1.6805***	4.9205***	3.6705***
	(4.4206)	(6.6006)	(5.4406)
c. GSIDMP #c.CDC	9.492***	12.34***	10.96***
	(0.583)	(0.678)	(0.993)
Constant	6.98*	7.42*	7.23
	(0.211)	(0.534)	(0.129)
No observations	1956	1956	1956
R squared	0.290	0.241	0.200
Number of group_id		304	304

Note: Standard errors in parentheses. CDC, companies' dynamic capabilities; GSIDMP, green strategic investment decision-making practices; OLS, ordinary least squares.
***$p < .01$, **$p < .05$, and *$p < .01$.

The regression results indicate a positive relationship between governance mechanisms, GSIDMP, and companies' financial performance. Governance mechanisms (ESG and board composition) mediate the relationship between companies' GSIDMP and financial performance, as Table 5 shows.

GSIDMP are shaped by a governance framework, and strategic investment options are analyzed and evaluated based on relevant assumptions and scenarios before financial investment is made, as illustrated by the narrative extracts from companies' annual reports.

> "The board assesses capital allocation across the bp portfolio, including the level and mix of capital expenditures and divestments, strategic acquisitions. The board reviews and approves capital investments that are more than $3 billion for investments in resilient hydrocarbon projects. More than $1 billion for investment in all non-oil and gas investments." (BP, AR, 2021, p.32)

> "For all investment cases, we consider whether the investment case supports the delivery of our strategy to become an integrated energy company and our net zero aims. We also assess if the investment case involves distinctive capability that bp has or intends to develop … We consider how any proposed business opportunity is connected to the energy transition, societal needs, and the environment." (BP, AR,2021, p.34)

TABLE 5 Governance mechanisms, GSIDMP, and companies' performance.

Variables	OLS performance	Fixed performance	Random performance
GSIDMP	6.2321*	6.0081*	6.0012*
	(6.1258)	(4.642)	(4.625)
Governance_mechanism	4.4706**	2.9905*	9.7406*
	(5.1206)	(1.7305)	(6.9606)
c.GSIDMP#c.Governance_mechanism	8.8110***	7.7710**	6.8010**
	(4.3210)	(1.9109)	(5.4310)
Constant	6.957**	8.743**	8.137**
	(0.659)	(1.694)	(0.937)
No observations	1940	1940	1940
R squared	0.202	0.180	0.080
No group-id		214	214

Note: Standard errors in parentheses. GSIDMP, green strategic investment decision-making practices. ***$p < .01$, **$p < .05$, and *$p < .01$.

5 | CONCLUSION

This study explores the influence of contextual factors surrounding green production and the GSIDMP and sheds light on current business innovation strategies. It examines the nexus between GSIDMP, technological innovation, dynamic capability, and companies' performance. Findings sheds lights on current business innovation strategies and explores current practices of production planning and GSIDM in large UK companies. This study offers insight into boardrooms' proactive engagement in exploration and exploitation activities and strengthens ambidexterity through various innovation trajectories associated with green production and GSIDMP toward sustainability. GSIDMP are shaped by boardrooms absorptive and adaptive capabilities, knowledge-generating and knowledge-collaboration capabilities, technological adoption, and corporate governance mechanisms. Our empirical analysis and extracts from companies' annual reports reveal how governance mechanisms and companies' dynamic capabilities can be viewed as pre-decision control mechanisms associated with production planning throughout the various stages of GSIDMP, including modifying existing products, developing new products, or creating new markets. Our findings confirm the view of Arranz et al. (2020) of the strong impact of innovation capabilities on eco-innovation strategies, and Singh et al.'s (2022) ambidexterity comprises balancing exploration and exploitation to achieve superior performance and enhanced competitiveness (Singh et al., 2022). Extracts from companies' annual reports reveal that technological adoption, reputation, heritage, partnerships, and collaboration with stakeholders through various innovation trajectories are key drivers of companies' dynamic capabilities and green production planning. The results of our empirical analysis revealed the combined impact of technological adoption, dynamic capability, and corporate governance on the correlation between the GSIDMP and company performance. The production planning and innovation trajectories inherent in GSIDMP in large UK companies are shaped by internal and external environments, including companies' dynamic capabilities, technological adoption, boardrooms' strategic agility, corporate governance mechanisms, national culture, and compliance issues with regulatory bodies and standard-setter requirements. The study's findings add to the extant literature on production planning and control, predominantly on the influence of contextual factors surrounding production planning and control through GSIDMP. The results of this study have managerial implications for decision-makers, regulators, investors, scholars, and other stakeholders.

UK companies are radically engaging in various trajectories of open innovation through production planning associated with GSIDMP, mainly through parentship and collaboration regarding knowledge acquisition. This is consistent with the results of previous studies (Brunswicker & Chesbrough, 2018; Chesbrough, 2020). Organizational resources, collaborative activities, and information sources are critical drivers of GSIDMP, significantly impacting innovation performance and leveraging companies' financial performance. Unsurprisingly, the results of this study reveal variations across industries in the radical innovation strategies embedded in GSIDMP. As highlighted by this study, internal R&D investment intensity is a critical driver of production innovation performance, and internal R&D investment is vital, as the innovation trajectory comprised more than 50% of companies' innovation investment expenditure over the period from 2016 to 2020. Internal and external R&D investment projects that leverage companies' dynamic capabilities (CDC) and product innovation strategies enable companies to maintain a competitive edge and achieve sustainable performance. Narrative extracts from companies' annual reports show that the intensity of R&D investment by UK companies is a crucial determinant of CDC. R&D investment leverages production innovation performance and value creation toward sustainable organizational performance, which is inconsistent with the findings of Alam et al. (2020). Collaboration arrangements by broader innovator companies mainly involve suppliers (more than 78% of businesses over the period 2018–2020); private and public customers (68% and 40%, respectively), other businesses within the group structure (50%), and competitors or businesses in the same sector (50%).

The results also highlight how boardrooms govern production planning and innovation activities through GSIDMP, recognizing the value added from open innovation derived mainly from national and international collaboration. Both manufacturing and knowledge-intensive service companies maintained their position as the largest innovative active companies from 2008 to 2020.

5.1 | Theoretical contribution

The extension of RBT through a natural resource-based view and dynamic capability can be a useful framework to gain a better understanding of green business innovation strategies, green product innovation, and GSIDMP. This study's findings offer insights into the current trend of business innovation strategies in the UK and how the complementarity among corporate governance structure, boardroom dynamic capabilities, and advanced technological innovation reinforce green production planning and GSIDMP toward sustainability. A key implication is that ESG considerations can be viewed as strategic pre-decision control mechanisms associated with production planning and GSIDMP; this perspective supports Alkaraan et al. (2023). The dynamic capabilities, knowledge generation, and knowledge sharing of boardrooms in various innovation trajectories, through partnerships and collaboration, play pivotal roles in successful business innovation strategies. The aforementioned complementarity domains generate organizational ambidexterity. This study offers insight into boardrooms' proactive engagement in exploration and exploitation activities and strengthens ambidexterity through various innovation trajectories associated with green production and GSIDMP toward sustainability. This study extends the literature on boardrooms, business innovation strategies, and sustainability governance.

5.2 | Managerial implications

The results have practical implications for future research. First, from a practitioner's perspective, this study sheds light on the key factors driving production planning and GSIDM in large UK companies. These predominantly include companies' dynamic capabilities, boardrooms' absorptive and adaptive capabilities, knowledge-generating and knowledge-collaboration capabilities, technological adoption, boardrooms' strategic agility, corporate governance mechanisms, and national culture. Companies in different countries and settings, predominantly emerging economies, may use the results of this study as benchmarks for rethinking their production planning strategies and strategic investment decision-making practices toward sustainable value creation and performance. Second, extracts from companies' narrative disclosures directly affect managers regarding the practical scenarios of how production innovation practices depend on external resources from different companies, partners, and collaborative activities with broad stakeholders. Findings of this study reveal how business environmental practices toward sustainability such as pollution reduction and waste management concerns are associated with GSIDMP in UK companies. Developing green product innovation through green operational processes take into consideration reducing the negative impact on the environment and prevent waste generation across the value chains and strengthening companies environmental and financial performance. GSIDMP do not take place in isolation, instead they are influenced by various contextual factors including national culture, internal and external corporate governance structure, and contingent on boardrooms commitment to environmental issues and stakeholders' concern. Boardrooms behaviors are shaped by cultural factors related to the national context. These contextual factors impact the relationship between companies' performance outcomes and GSIDMP. Finally, this study may help companies reshape their existing policies on investments in industries and direct them to manage their working capital effectively with a focused on green innovation strategies, GSIDMP, and operations strategies.

5.3 | Limitations and future research directions

This study examines the influence of key contextual factors surrounding production planning activities and innovation trajectories associated with the GSIDMP in large UK companies. By adopting or adapting the methodology and context of this study, future research could examine the influence of contextual factors on production planning and GSIDMP in different contexts and settings. Future research can use a combination of companies' dynamic capability lenses and strong structuration theory to examine the role of other agents in a given context and their influences on production innovation management (the agents in focus). Future research may employ other theoretical lenses such as resource dependence theory, new institutional theory, upper echelons theory, production economics, and industrial marketing. This study also provides scope for studying the interrelation of these contextual factors and ways to prioritize them.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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