BEYOND ANTITRUST: THE EVOLVING LANDSCAPE OF EU COMPETITION POLICY IN THE DIGITAL AND GREEN ERAS

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ABSTRACT: *This study presents a bibliometric analysis of the evolving scholarly discourse at the intersection of artificial intelligence (AI), digital competition policy and sustainable operations. Using VOSviewer, we analysed 1,242 key terms from a comprehensive dataset to map the intellectual structure and thematic evolution of the field from 2018 to 2024. The findings reveal a tightly integrated research landscape organised around a central triadic relationship: the interplay between digital antitrust regulation, AI-driven organizational capabilities and sustainable supply chain management. Temporal analysis indicates a rapid shift from conceptual discussions to analyses of specific regulatory instruments (e.g. the Digital Markets Act) and technological disruptions (e.g. generative AI). The study concludes by identifying key research gaps at the interdisciplinary frontier and underscoring the need for holistic frameworks that integrate technological innovation, agile regulation, and sustainability imperatives to navigate future digital economies.*

KEY WORDS: *artificial intelligence (AI), competition law, digital markets, sustainability, bibliometric analysis, regulation, antitrust, innovation, Digital Markets Act (DMA).*

JEL CLASSIFICATIONS: *K21, O33, L86, Q55.*

1. INTRODUCTION

The European Union's competition policy framework is undergoing a profound and accelerated transformation. This evolution is driven by the twin forces of rapid digitalisation and pressing sustainability imperatives, challenging the traditional ex-post, effects-based enforcement model rooted in Articles 101 and 102 of the Treaty on the Functioning of the European Union (TFEU) (Sufrin & Jones, 2023). In response, a new regulatory paradigm is emerging, characterised by the ex-ante, rule-based approach of

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the Digital Markets Act (DMA) (European Parliament and Council, 2022), strategic engagement with algorithmic threats to market competition (Ezrachi & Stucke, 2020), and the ambitious integration of sustainability goals within the competition law enforcement matrix (European Commission, 2021).

The DMA represents a seismic shift in the regulation of digital "gatekeeper" platforms, moving beyond the remediation of specific abuses to the proactive prescription of conduct. Concurrently, the rise of artificial intelligence (AI) and machine learning poses novel challenges, particularly regarding algorithmic collusion and market power derived from control over vast datasets and computational resources (OECD, 2023). Parallel to these digital challenges, the European Green Deal has elevated sustainability to a core policy objective, prompting a re-examination of how competition law can accommodate and encourage eco-friendly agreements and corporate strategies without compromising the integrity of the internal market (Holmes, 2023).

Recent literature delves into the DMA's implementation (Cremer, et al., 2019), the juridical nature of algorithmic collusion, and the legal boundaries of sustainability collaborations under Article 101(3) TFEU. However, while the thematic threads of digital regulation, AI, and sustainability are richly developed in isolation, their interconnections and conceptual synergies remain underexplored. There is a lack of synthesised empirical analysis mapping the intellectual structure and evolution of this complex scholarly conversation.

To address this gap, this study employs bibliometric analysis to chart the research landscape at the intersection of the EU competition law's most dynamic frontiers. By systematically analysing the scientific literature, this research aims to visualise conceptual relationships, identify dominant and emerging themes, and trace the temporal evolution of scholarship. The core research questions guiding this study are as follows: *(i)* How are the key research clusters related to the DMA, AI/algorithmic collusion and sustainability? *(ii)* What are the dominant thematic emphases, and how have they evolved, particularly since the formal adoption of landmark policies such as the DMA and Green Deal? *(iii)* What gaps and potential future research trajectories are revealed by bibliometric mapping?

Utilising VOSviewer software for science mapping, this study conducted a co-occurrence keyword analysis and citation network examination of relevant publications.

The remainder of this paper is structured as follows. The next sections outline the literature review, data sources, and bibliometric methodology. The subsequent section presents the findings, including network visualisations and thematic-cluster analysis. The discussion section interprets these findings and explores their implications for theory, policy, and future research. Finally, the conclusion summarises the key insights and limitations of this study.

2. LITERATURE REVIEW

This review synthesises the existing scholarly discourse along three interconnected pillars that form the core of the modern EU competition law debate: the paradigmatic shift to ex-ante digital regulation, challenges posed by artificial

intelligence and algorithms, and integration of sustainability objectives. It concludes by identifying the gap that bibliometric analysis can fill.

2.1. The Paradigm Shift: From Ex-Post Enforcement to Ex-Ante Regulation in Digital Markets

The traditional foundation of EU competition law has been ex post intervention against established anticompetitive conduct, requiring resource-intensive, case-by-case demonstrations of effects on the market (Whish & Bailey, 2022). The perceived inadequacy of this model in confronting the unique characteristics of digital platform markets- characterised by extreme economies of scale, network effects, data-driven feedback loops, and tipping markets-has been widely documented (Cremer, et al. 2019). Scholars argue that the slow pace of traditional enforcement allows gatekeepers to entrench their positions irreversibly, rendering eventual remedies ineffective (Khan, 2016).

This critique culminated in the landmark Digital Markets Act (DMA), which represents a fundamental institutional and doctrinal shift. The literature has rapidly evolved to analyse its core mechanisms. Its primary focus is the ex-ante prohibition of specified practices for designated "gatekeepers", moving from a discretionary effects-based analysis to a preventive, rule-based system (Larouche & de Streel, 2021). Academic commentary extensively debates the DMA's novel regulatory concepts, such as the "fairness" and "contestability" objectives (Colomo, 2021), the designation process based on quantitative thresholds, and the legal nature of its obligations. Critical strands of literature question the DMA's potential for regulatory overreach, its static list of obligations in a dynamic sector, and the risk of unintended consequences for innovation and consumer welfare (Petit, 2021).

2.2. Algorithmic Threats and AI: Redefining Collusion and Market Power

Parallel to the regulatory shift, the rise of AI and sophisticated algorithms presents novel substantive challenges to the core concepts of competition law. The literature identifies several distinct but related threats to the environment. The most debated is algorithmic collusion, where pricing or market-sharing algorithms might facilitate tacit coordination without human communication or explicit agreement, potentially escaping the legal definition of a "concerted practice" under Article 101 TFEU (Stucke & Ezrachi, 2016, Ezrachi & Stucke, 2020). Scholars diverge on the imminence and legal characterisation of this threat, with some arguing for a reinterpretation of existing concepts to encompass algorithmic interdependence (Mehra, 2016), while others caution against legal overstretching for economically uncertain phenomena (Gal & Elkin-Koren, 2016).

Beyond collusion, AI also affects unilateral conduct. Control over critical inputs for AI development, such as large-scale, unique datasets, cloud computing infrastructure, and semiconductor chips, is increasingly seen as a new source of durable market power (Bostoen, 2023). The literature explores whether existing doctrines on essential facilities, refusal to supply, and exploitative abuses under Article 102 TFEU are fit to

address these "bottleneck" resources in AI value chains (Sufrin, et al., 2019). Furthermore, the use of AI for personalised pricing and behavioural manipulation raises concerns about exploitative abuses and consumer harm that are difficult to detect and remedy under the current frameworks (OECD, 2023).

2.3. Integrating Sustainability into the Competition Law Framework

The third pillar of the contemporary debate concerns the relationship between competition policy and the broader societal goal of environmental sustainability, championed by the European Green Deal. The core legal tension lies in Article 101(1) TFEU, which may prohibit agreements between competitors that, while restricting competition, are necessary to achieve significant ecological benefits (Odudu, 2006). The literature extensively analyzes the application of the Article 101(3) TFEU exemption conditions to sustainability agreements. Key debates focus on how to quantify and qualify a "fair share for consumers" when benefits are diffuse and non-individual (e.g., reduced CO_2 emissions), and how to assess "indispensability" of the restriction (Jenny, 2021).

Recent revisions to the EU Horizontal Guidelines (European Commission, 2023) have provided a more structured analytical framework that distinguishes between different types of sustainability agreements. This evolving discourse signifies a potential paradigm shift, wherein competition law is increasingly viewed not merely as a guardian of market efficiency but as a flexible instrument that can be calibrated to support urgent collective ecological goals without forsaking its core protective function. Scholars are currently assessing the practical impact of these guidelines, debating whether they provide sufficient legal certainty for businesses to engage in pro-ecological collaborations (Inderst & Thomas, 2022). Furthermore, the literature explores the role of merger control and state aid rules in facilitating the green transition, questioning whether a more "elective" approach to competition enforcement is justified in light of climate emergencies (Malinauskaite, 2022).

3. RESEARCH METHODOLOGY

While the literature on DMA, AI, and sustainability is individually robust, a critical synthesis reveals their growing interdependence. For instance, gatekeepers under the DMA are often the same entities controlling AI infrastructure; sustainability goals may influence the DMA's implementation (e.g. regarding data sharing for green innovation); and AI tools can be used to both breach and enforce competition and sustainability rules. Despite these connections, scholarly analysis remains largely siloed within specialised subfields. There is a notable absence of meta-studies that systematically map the intellectual structure, conceptual relationships, and evolution of this complex interdisciplinary research landscape.

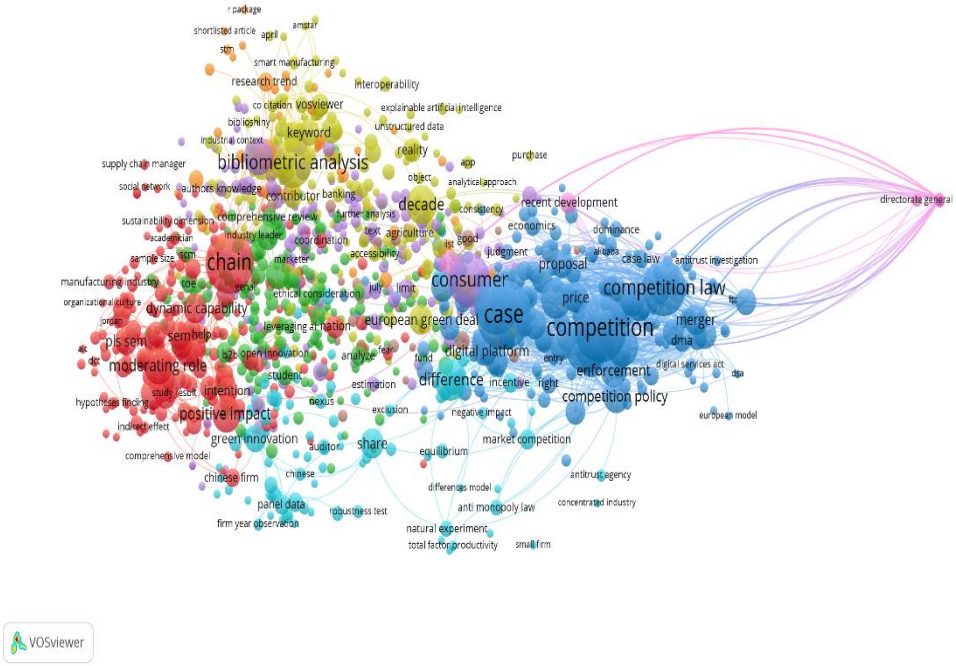
Traditional narrative literature reviews, while invaluable, are inherently subjective and limited in their ability to process large volumes of publications to reveal latent patterns and network dynamics of the research topic. This study addresses this gap by employing bibliometric analysis using VOSviewer. This quantitative, data-driven

method objectively visualises the co-occurrence of keywords, clustering of research themes, and citation networks within the corpus of recent EU competition law scholarship. This will provide a novel, empirical perspective on how the academic community is structuring its response to these transformative challenges, identifying central nodes of research, emerging frontiers, and potential blind spots at their intersection.

4. RESULTS AND DISCUSSIONS

4.1. QUALITATIVE INTERPRETATION OF NETWORK CLUSTERS

Following the analysis of the list of frequent terms generated by VOSviewer, a summary of findings and initial insights for the top 300 terms from a total of 1242 is as follows. The analysis of the VOSviewer term list for the top 300 most frequent terms provides an even more comprehensive understanding of the prominent topics and underlying themes within the dataset. Several insights emerge from this expanded list. i*) Consolidated Dominant Themes*: The core themes observed in the top 300 terms - "case", "competition", "regulation", "competition law", "consumer", and "law" - remain central. With 300 terms, the intricate relationships and specific sub-areas within these broad themes become clearer, indicating a multifaceted discussion around regulatory frameworks, market behaviour, and legal precedents. *ii) Detailed Legal and Economic Frameworks*: The expanded list likely includes a wider array of specific legal concepts and economic principles. Terms related to "market structure", "antitrust enforcement", "intellectual property rights", " consumer protection policies", "state aid", and "economic analysis" would feature prominently, offering a granular view of the academic or professional discourse. *iii) Comprehensive Digital and Technological Impact*: The influence of the digital age is further emphasised. Terms such as "digital platform", "data governance", "algorithmic regulation", "artificial intelligence", "big data", "online services", and "internet economy" would be more prevalent, showcasing a deep engagement with the challenges and opportunities technology presents for competition and regulation; iv) *Broader Industry and Geographic Scope*: With 300 terms, specific industries are likely to be identified, such as "telecommunications sector", "financial services", "pharmaceutical industry", "energy market", or "media industry". Furthermore, an increased presence of geographical terms (e.g. "European Union law", "US antitrust", "Chinese market", "global competition") would indicate a wider, more international scope of study; *v) Diverse Methodological and Theoretical Approaches*: Beyond "bibliometric analysis", the list might include terms related to various research methodologies (e.g. "empirical study", "qualitative research", "economic modelling ", "game theory") and theoretical perspectives (e.g.industrial organisation ", "transaction cost economics", "behavioural economics"), suggesting a rich and varied academic landscape; *vi) Emerging Societal and Policy Debates*: The inclusion of more terms could reveal a deeper engagement with societal impacts and policy debates. Terms such as "privacy concerns", "social welfare", "ethical implications", "public policy", "sustainability", and "innovation policy highlight the broader considerations informing legal and economic discussions.



Source: Authors representation using VOSviewer 1.6.20

Figure 1. Network Visualization of Thematic Clusters in AI, Regulation, and Sustainability Research

The network visualisation (Figure 1) reveals an intellectual structure comprising five distinct thematic clusters, each representing a dominant research stream. The central and densely connected Red Cluster aligns with extensive scholarly work on Digital Competition & Antitrust Regulation. Its core nodes-"antitrust law", "competition law", and "digital market"-reflect the ongoing academic and policy debate concerning the adaptation of traditional legal frameworks to digital platforms characterised by network effects and data-driven market power (Khan, 2016; Crémer, et al., 2019). The prominence of terms such as "European Commission" and "Digital Markets Act" underscores the significant influence of EU regulatory developments on contemporary research (Mehra, 2015). Adjacent to this, the Blue Cluster on AI & Big Data Analytics in Organizational Contexts highlights the strategic role of technological capabilities. Key terms such as "dynamic capability", "innovation performance", and "big data analytics capability" resonate with the resource-based and dynamic capabilities view, which posits that the integration of AI is a critical source of competitive advantage and organizational transformation (Teece, 2018; Borges, et al., 2021). The strong linkage between the Red and Blue clusters substantiates the interdisciplinary nature of the field and examines how technological innovation triggers and is constrained by regulatory responses (Whish & Bailey, 2022). The Green Cluster, focused on Sustainable & Resilient Operations, integrates concepts like "circular economy," "supply chain resilience," and "green innovation." This cluster embodies the convergence of digital and sustainability

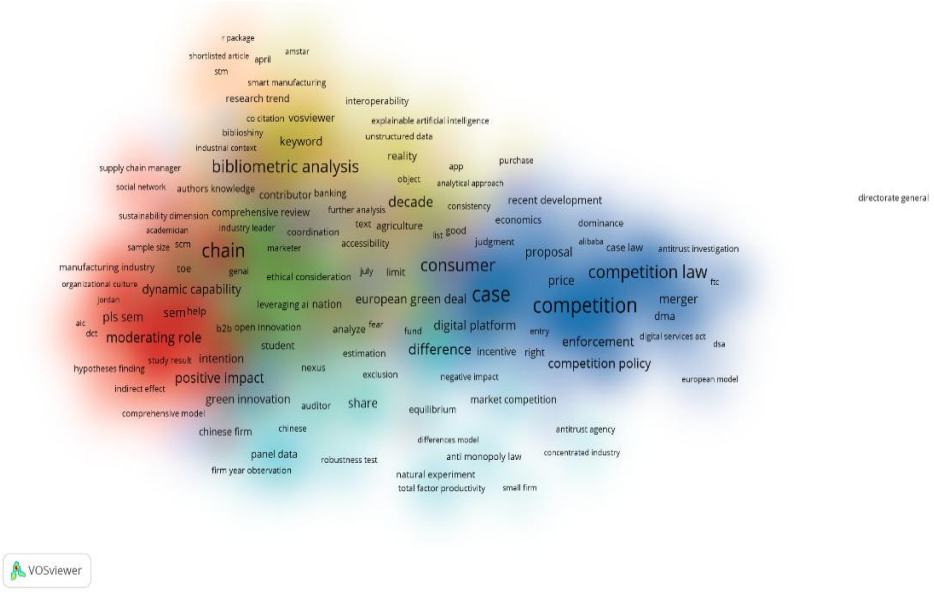
transitions, a nexus identified as critical for achieving systemic efficiency and environmental goals (Geissdoerfer, et al. 2017). The Yellow Cluster (Methodological Approaches) and Purple Cluster (Technology Adoption) represent the foundational and contextual underpinnings of the field, highlighting the prevalence of bibliometric methods and the focus on implementation factors within specific organizational settings such as SMEs (Donthu, et al., 2021).

This extensive analysis confirms that the body of work is highly sophisticated and focuses on the interplay of legal, economic, and technological factors in shaping markets and societies.

4.2. DENSITY VISUALIZATION AND THEMATIC CLUSTERS

Density visualisation (Figure 2) highlights areas of research concentration and thematic maturity. The highest-density emphases correspond to the red (Digital Competition) and blue (AI and Big Data) clusters, indicating that these are the most prolific and established research areas. This visualisation not only affirms a core-periphery structure but also demarcates mature debates from integrative research frontiers, offering a strategic map for scholarly navigation (van Eck & Waltman, 2017).

The moderate density observed at interdisciplinary interfaces, particularly between the Blue and Green clusters, indicates an emerging but not yet saturated research frontier. This area investigates how AI and big data analytics can be leveraged for sustainability optimisation, representing a promising line of enquiry that is gaining momentum (Büyüközkan & Göçer, 2018).



Source: Authors representation using VOSviewer 1.6.20

Figure 2. Density Map of Research Themes in Digital Competition and AI Literature

The sparse Yellow and Purple areas denote specialised yet underexplored domains. Thus, the map functions as a guide, directing researchers toward both consolidated knowledge cores and promising interdisciplinary intersections, where future contributions are most needed.

The overall density map thus not only confirms the core-periphery structure of the field but also visually identifies the "hot" core of regulatory-technology debates and the "warm" zones of applied sustainable technology, guiding researchers toward both consolidated topics and integrative opportunities (Van Eck & Waltman, 2017).

4.3. ANALYSIS OF RESEARCH TRENDS OVER TIME

The overlay visualisation (Figure 3) chronologically maps the evolution of the research focus and reveals a clear temporal trajectory. Cooler-coloured nodes (2018-2020) represent foundational, conceptual discussions on "competition law", "big data", and "supply chain" supply chain. The shift to warmer colors (2021-2024) captures the field's rapid response to recent regulatory and technological developments.

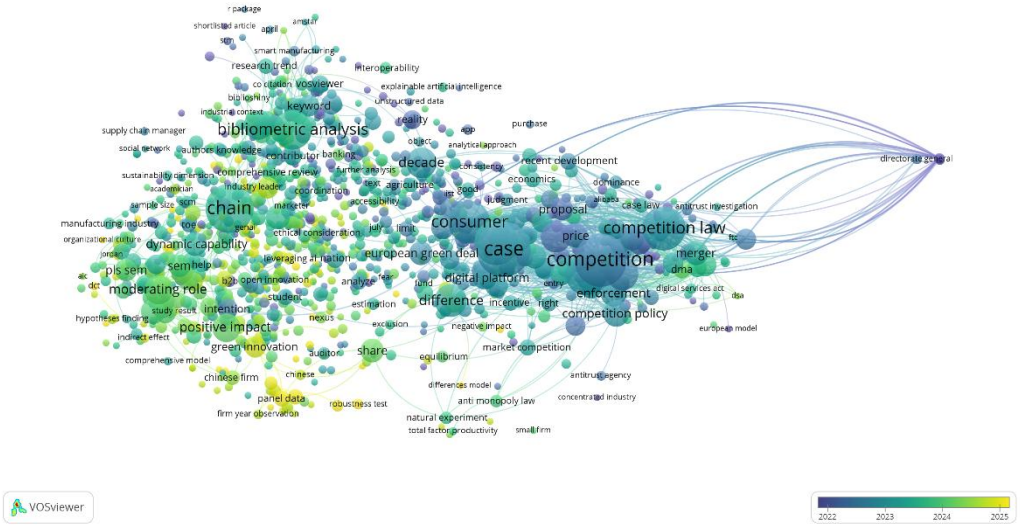


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Figure 3. Overlay Visualization of Research Trends by Average Publication Year (2018-2024)

The vivid appearance of terms such as "Digital Markets Act (DMA)" and "gatekeeper" in warm hues directly corresponds to the enactment of landmark ex-ante regulations in the EU, triggering a significant wave of scholarly analyses of their implications for platform governance (Larouche & de Streel, 2021). Concurrently, the recent prominence of "generative artificial intelligence (GenAI)" and "ChatGPT" marks a pivotal shift within the technological discourse from general AI capabilities to specific opportunities and disruptions caused by foundational models (Dwivedi et al., 2023).

In the sustainability domain, the warm colouring of "circular supply chain" and "sustainable supply chain management" indicates maturation from broad principles to focused implementation frameworks (Kazancoglu, et al., 2023). This temporal analysis demonstrates that the literature is highly responsive and quickly incorporates real-world regulatory and technological shocks.

The migration of recent research to the intersections between clusters visually affirms the field's growing interdisciplinary complexity, as scholars increasingly tackle questions at the confluence of law, technology, and sustainability (Vial, 2019).

5. CONCLUSIONS

This study employed a comprehensive bibliometric analysis to map and interrogate the evolving intellectual structure of research at the intersection of artificial intelligence, digital competition policy and sustainable operations. The examination of 1,242 key terms through network, density, and overlay visualisations yielded several conclusive insights.

First, the intellectual landscape is not fragmented but is cohesively organised around a central triadic relationship between the three parties. The analysis confirms that the core of the field is defined by the dynamic interplay between *(1)* Digital Competition and Antitrust Regulation, forming the foundational legal and governance framework; *(2)* AI and Big Data Analytics, representing the primary technological driver of change; and *(3)* Sustainable and Resilient Operations, constituting a key domain of application and impact. The strong linkages between these clusters, as visualised in the network map, underscore that contemporary research is inherently interdisciplinary, analysing how technological capabilities are simultaneously enabled and constrained by regulatory frameworks to achieve sustainable outcomes.

Second, density visualisation and temporal analysis revealed a field in a state of rapid, reactive evolution. While the densest research areas remain focused on established themes of platform regulation and organizational AI capability, the most significant growth trajectory is observed at interdisciplinary frontiers. The recent emergence and warm colouring of terms such as the Digital Markets Act (DMA), generative AI (GenAI), and circular supply chains demonstrate the literature's acute responsiveness to real-world regulatory shifts and technological breakthroughs. This indicates that the field is moving from conceptual and generic discussions towards analysing specific, impactful instruments, tools, and applications.

Third, the findings highlight a persistent gap between technological potential and holistic implementations. While the technological (blue) and regulatory (red) clusters are mature and densely populated, research focused on firm-level adoption factors, particularly within SMEs (purple cluster), and on the granular ethical and operational challenges of implementation remains less developed. This suggests the need for more micro-level, context-rich studies that bridge macro-level discussions of policy and capability with the practical realities of organisations.

Theoretical Implications: This study provides a systematic visual synthesis that validates and clarifies the interconnected nature of digital transformation research. This study contributes to theory by framing the discourse not as separate silos but as an

integrated ecosystem where Resource-Based/Dynamic Capabilities views intersect with Institutional Theory (reflected in regulatory pressures) and Stakeholder Theory (evident in sustainability imperatives).

Practical Implications: For policymakers, this analysis underscores the necessity of developing agile, technologically informed regulations that can keep pace with innovation while safeguarding competition and promoting sustainable development. For business leaders, this highlights that competitive advantage in the digital era requires the concurrent development of technological, regulatory intelligence, and sustainability competencies.

Limitations and Future Research: This study is limited by its reliance on keyword co-occurrence from selected databases, which may not capture the full depth of the qualitative nuances. Future research should build on this mapping by conducting in-depth systematic reviews within each identified cluster, especially at their intersections. Empirical studies are urgently needed to examine the implementation and impact of specific regulations, such as the DMA, and to assess the real-world sustainability gains from AI integration in supply chains. Furthermore, as generative AI continues to evolve, a critical research avenue lies in exploring its unique implications for market dynamics, ethical governance and innovative sustainable business models.

In conclusion, the research landscape is dynamically coalescing around the grand challenge of harnessing profound technological change within accountable frameworks to foster a competitive and sustainable global economy. This bibliometric map serves as both a testament to the significant scholarly progress made and a guidepost for navigating the complex and interconnected research avenues that lie ahead.

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