

A meta-analysis on the barriers of digital technology adoption - a multi-level and multi-topic framework

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1. Introduction



2. Literature review



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Introduction

Our two-dimensional classification, starting at the item level, enables quantified meta-analysis of DT's barriers. We propose a multi-level and multi-topic framework to organise and analyse DT's barriers.



Research question

RQ1: What are the most frequent barriers to DT?
RQ2: What is the thematic direction of papers?
RQ3: What are the differences in DT barriers between countries with higher or lower digital competitiveness?
RQ4: How can we describe the interplay of barrier categories at each level and what are the barrier categories that play the role of interface by bridging levels?



Theoretical relevance

The framework we developed along multiple levels and perspectives makes the investigation **more complete than previous studies.**



Practical relevance

Full and structured picture of barriers makes it **easier for companies and governmental policies to be prepared and take counteractions to potential barriers.**



Data and methodology

Meta-analysis: **complex and organised picture of its barriers based on 90 empirical articles. 54 overall barriers** that form a cohesive unit of analysis representing the **353 lower-level items.**

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Literature review

Digitalization has generated two streams of discussion on managing DT successfully. The minor stream of the discussion identifies the success factors of adoption. A more extensive stream with more studies is about the barriers of DT.



Multi-level models

Main theoretical basis: the multi-level theory.

Kozlowski & Klein (2000), „*fundamental to the levels perspective is the recognition that **micro phenomena are embedded in macro contexts and that macro phenomena often emerge through the interaction and dynamics of lower-level elements.***” (p.5.)



Discovering both micro and macro levels and their relationship is critical to understanding systems and processes.



Multi-topic approach

Existing literature reviews have comprehensively analysed the impact of digitalisation in terms of **management challenges, organisational structure, supply chain performance, human resource management, and strategic considerations.**



Process view with inputs, transformation process and output, considering the result of digital transformation as the output.

Multi-level and multi-topic framework

Our two-dimensional classification, starting at the item level, enables quantified meta-analysis of DT's barriers.

Literature review

To organise topics, we follow a process view with inputs, transformation process and output, considering the result of digital transformation as the output.

Authors	Level ¹	Topics of barriers (shortlist)	Developing / Developed	N ²
Ghobakhloo et al., 2022	<u>IFGC</u>	Technological: High costs, complexity, compatibility and cybersecurity risks, investment risks; Organizational: Lack of digitalization knowledge and expertise, limited transformation management strategies, rigid culture, lack of IT and OT readiness, resource availability; Environmental: Weak government support, stakeholder pressure, lack of technology accessibility; external partnership and supply chain incoordination; value chain readiness; technology vendor monopolies.	SMEs globally exhibit a slow pace of I4.0 digitalization; developing nations lag, and their challenges intensify.	37
Nayernia et al., 2022	<u>IFGC</u>	Industry and Firm Level: Government overregulation, lack of industry standards; need for technology competence and the shortage of skilled HR; lack of skilled HR, insufficient management support; structural/cultural rigidity; Smart Factory Level: Legacy system incompatibility; technology complexity; data integration challenges; cybersecurity risks; Data Level: Data privacy concerns, lack of real-time data capability; HR Level: Job loss fears; lack of digital skills; resistance to training; Supply Chain Level: Lack of inter-organizational collaboration; fear of losing bargaining power and data security issues.	Drivers for adopting I4.0 vary due to different government policies and regulations. Overcoming unique regional and county-specific barriers inherent in emerging and developed economies requires a context-specific and tailored approach.	97
Schneider, 2018	<u>IFGC</u>	Analysis and strategy: Ability of valuing market impact, determining strategic approaches, developing transformation paths; Planning & Implementation: Making a sound assessment of the overall effect of Industry 4.0 investments; Cooperation and networks: Have appropriate strategic alliances and collaborative partnerships, data security, potential loss of know-how; Business models: Challenge of deciding to adapt/extend value propositions, innovation uncertainty; Human resources: Skill gaps, resistance to role changes, lack of digital capabilities and interdisciplinary expertise; Change and leadership: Resistance to manage the transformation organizationally, cultural inertia.	Brownfield scenarios reflect the practical constraints of mature economies. In developed countries, the core dilemma of Industry 4.0 lies in achieving a technological leap while preserving existing industrial assets.	93
Matt et al., 2023	<u>IFGC</u>	Organizational barriers: Sceptical attitude (toward the advantages envisaged by a digitalized industry), cultural rigidity, lack of commitment and motivation, implementation and opportunity costs; Market barriers: Unreadiness of customers and suppliers, uncertainty about future market conditions; Institutional barriers: Legal framework (also include the absence of tailored privacy and security rules to cope with the risk entailed by the diffusion of cybercrime and data violation, and the lack of institutional and legal norms governing blockchain technologies is causing delays in its implementation), lack of government support, Social and ethical barriers: Poor social acceptance, the failure to address the ethical issues raised by digitalization.	Developed countries are witnessing a resurgence in the role of manufacturing. Studies on this topic are concentrated in Europe; studies from developing continents are underrepresented.	142
Rad et al., 2022	<u>IFGC</u>	Cost: High upfront investments (e.g., blockchain, IoT infrastructure); Technological infrastructure: Lack of suitable systems (e.g., IoT alignment, AM software-printer compliance); Human resources and artificial divide; Big data governance and security (privacy concerns, cybersecurity threat, information leakage, legal issues and technical issues); Control and coordination; Business adjustment; Altering smart contracts and information capture.	Not directly mentioned	221
Ammirato et al., 2023	<u>IFGC</u>	Technological: Vulnerability and HR security-related issues; Human-centric: Potential negative impacts on workers' well-being, authoritarian governance by one person in total control of network power; Organizational: Challenges of the (fast) changes required to employees' competences by I4.0.	Not directly mentioned	556
Vial, 2021	<u>IFGC</u>	Inertia: Path dependence, cultural/structural resistance to change, organizational institutional barriers (formed by culture, identity and legitimacy), leadership disconnect (top management underestimates digital technologies' strategic value) Resistance: Employee Resistance; lack of visibility on the potential benefits of digital technologies, skill gaps	Not directly mentioned	282
Rêgo et al., 2021	<u>IFGC</u>	External Environment Barriers: Industry-specific barriers due to digital transformation, knowledge protection. Internal Environment Barriers: Organizational culture conflicts, increase the need for organizational change, demands for changes in leadership roles, and internal resource availability.	Not directly mentioned	45
Jones et al., 2021	<u>IFGC</u>	Technology: Data insufficiency and unreliability, absence of benchmarks and reference architecture, complexity in integrating systems, low maturity levels of technology, cybersecurity threats, and unsuitable infrastructure; Strategic: Alignment/ integration, lack of effective strategy and misunderstanding disruptive innovation; Organizational: Skill gaps and their development, managerial and cultural; Mindset: Perception of technology, fixed or growth mindset, perception of disruptive innovation; Societal: Individual barriers (such as fear of job loss), regulatory; Environmental: Risk management.	Not directly mentioned	N/A
Zamani, 2022	<u>IFGC</u>	Technological: Compatibility, complexity, relative advantage; Environmental: Competitors' pressure, customers' pressure, external support; Management: Top management support, top management commitment and consistency; Organizational: Firm size and age; Knowledge: Employees' knowledge and change resistance; Financial: Cost of adoption, lack of financial resources; Strategic: Perceived risk, inefficiency in strategic orientation, lack of clear strategy, poor communication; Regulations: Lack of government support, Legal environment constraints; Infrastructure: IT infrastructure gaps.	It examines the geographical distribution of technology adoption in SMEs and discusses the role of top management support in developing countries, but does not compare barriers between developed and developing economies.	349

Legend: (1) Levels: individual, firm, group of companies, country /// (2) It shows the number of articles processed in the given paper

Literature review

To organise topics, we follow a process view with inputs, transformation process and output, considering the result of digital transformation as the output.

Authors	Level ¹	Individual	Firm	Group of companies	Country
Ghobakhloo et al., 2022	<u>IFGC</u>		•	•	•
Nayernia et al., 2022	<u>IFGC</u>	•	•	•	•
Schneider, 2018	<u>IFGC</u>	•	•	•	
Matt et al., 2023	<u>IFGC</u>	•	•	•	•
Rad et al., 2022	<u>IFGC</u>		•	•	
Ammirato et al., 2023	<u>IFGC</u>	•	•		
Vial, 2021	<u>IFGC</u>	•	•		
Rêgo et al., 2021	<u>IFGC</u>		•	•	
Jones et al., 2021	<u>IFGC</u>	•	•	•	
Zamani, 2022	<u>IFGC</u>	•	•	•	

Legend: (1) Levels: individual, firm, group of companies, country

Literature review

Our framework has 4 levels following the multilevel theory and 12 topics (categories) at each level covering the key process characteristics of digitalization.

Topics



Levels

Barriers (topics)	Direction	Resources					Coop. between resources	Perspectives				Other
		Technological resource		Human resources				Financial	Legal	Material	Information	
	Strategy	Technology	Integration and infrastructure	Leadership	Human resources	Culture	Cooperation	Economic / financial	Legal	Process / project execution	Data management / security	Other
Individual												
Company												
Group of companies												
Country												

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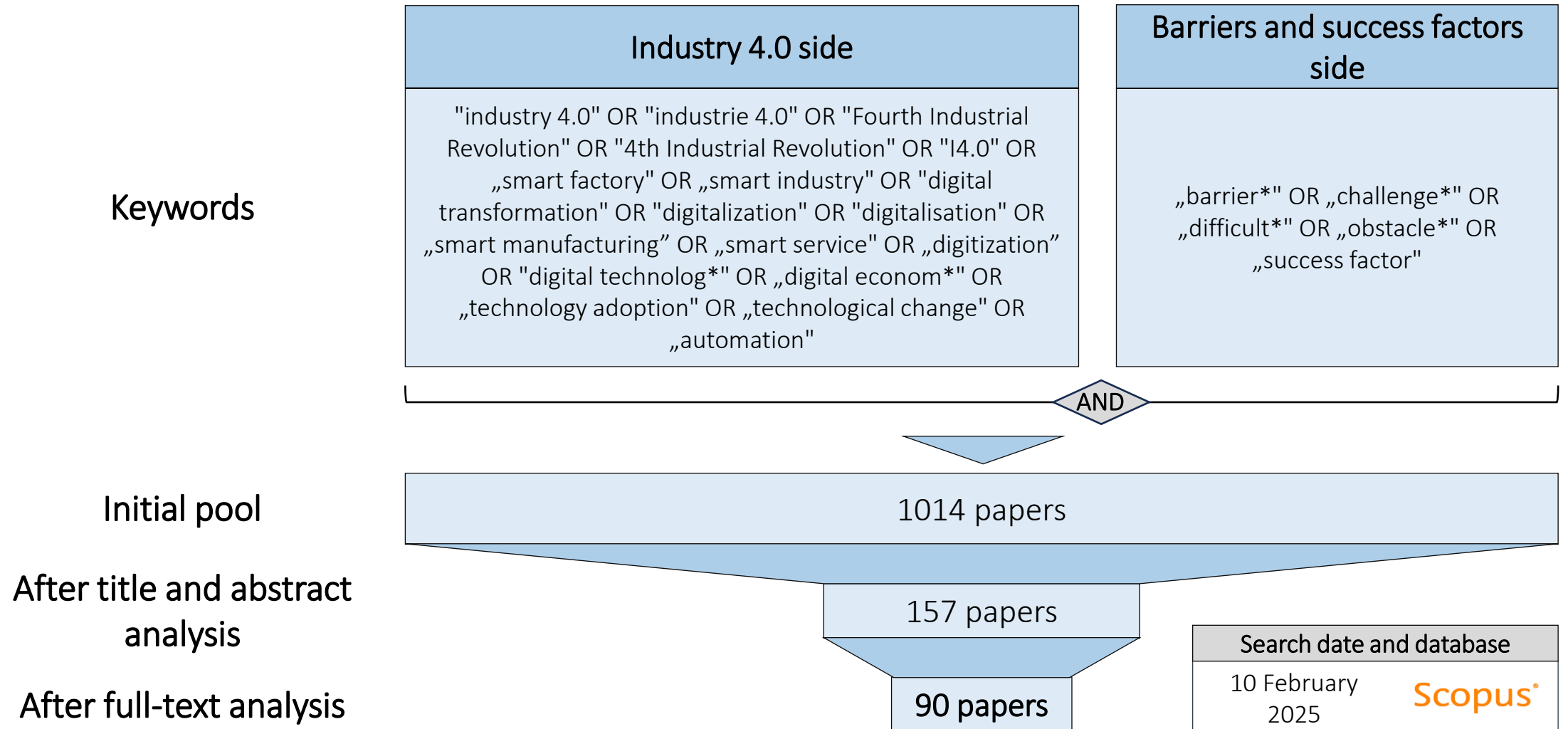
Inclusion criteria

Several inclusion criteria have been defined to create a relevant initial pool of sources.

Inclusion criteria	Detailed argument
 (a) Papers written in English.	English is the dominant research language in business and economics research; the use of English ensures the accessibility and comparability of our results.
 (b) Papers published in or after 2012	The concept of I4.0 appeared in 2012 (Kagermann et al., 2013; Liao et al., 2017). Although some constituent technologies appeared earlier, 2012 can be considered as the seminal point of the I4.0 literature stream.
 (c) Type of publication: scientific article	We focus only on high quality, peer-reviewed scientific papers, where a rigorous review process ensures the reliability of the results. Other publication types, such as conference papers or book chapters are excluded. Literature reviews and conceptual papers were also excluded, only the empirical papers were analysed.
 (d) Based on its topic, the journal is included in at least one of the Social Sciences, Business, Economics, Decision Sciences and Psychology domains in Scopus	This review exclusively addresses economic-related barriers to digital transformation, focusing solely on topics related to the economy. However, as barriers related to individuals can be numerous within the psychology topic, we have also included this topic in our analysis.
 (e) The journal is listed on the ABS list	With the use of the ABS list, this research aims to focus on papers of genuine quality.
 (f) The paper applies an empirical approach	However, during the search, literature review papers were excluded, even though some of them also comprised the list. Consequently, we excluded all types of literature reviews and purely conceptual papers, relying on empirically proven results.
 (g) The paper is relevant	The relevance of the papers was operationalized using keywords, but researchers manually evaluated each paper to obtain a fully relevant sample. For example, a relevant paper addresses barriers while ensuring that its focus on technology is not overly narrow. In numerous cases, the papers either touched on the topic of barriers lightly or were excessively technology focused.

Keyword selection

As an operationalization of the last inclusion criterion (g), several keywords have been defined to discover potentially relevant articles. Keywords were defined in relation to the two main domains of investigation, i.e., I4.0 and barriers or success factors.

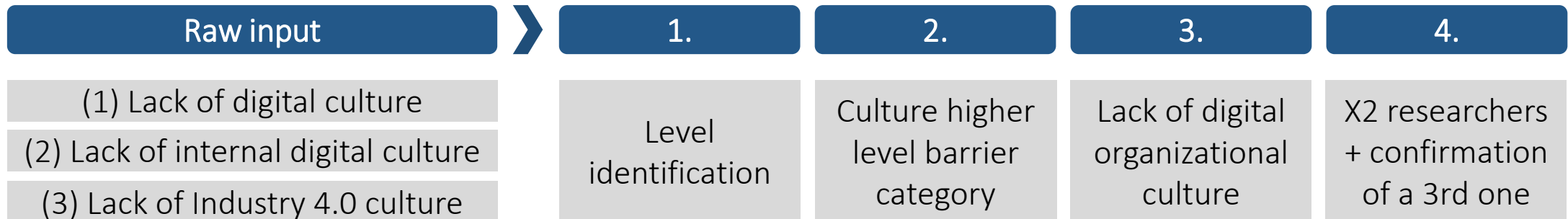


Coding and categorization

During this identification, each barrier was also linked to a particular level. Subsequently, we classified the barriers. This thematic classification resulted in many meaningful clusters.

1. Each barrier was also linked to a particular level.
2. Thematic classification: resulted in many meaningful clusters (N = 353).
3. Classifying these clusters, we derived 54 overall barriers.
4. 2 researchers independently analysed each paper. A third team member reviewed and confirmed their final classifications.

Example



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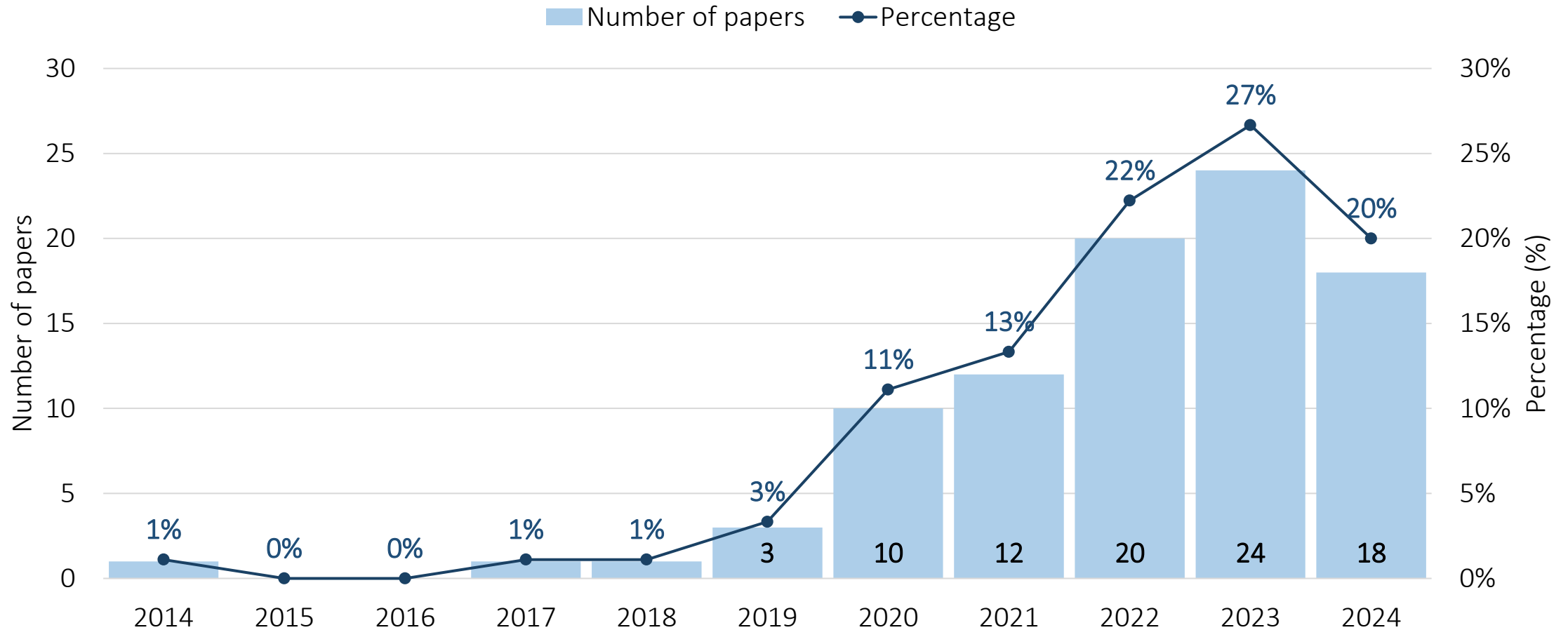


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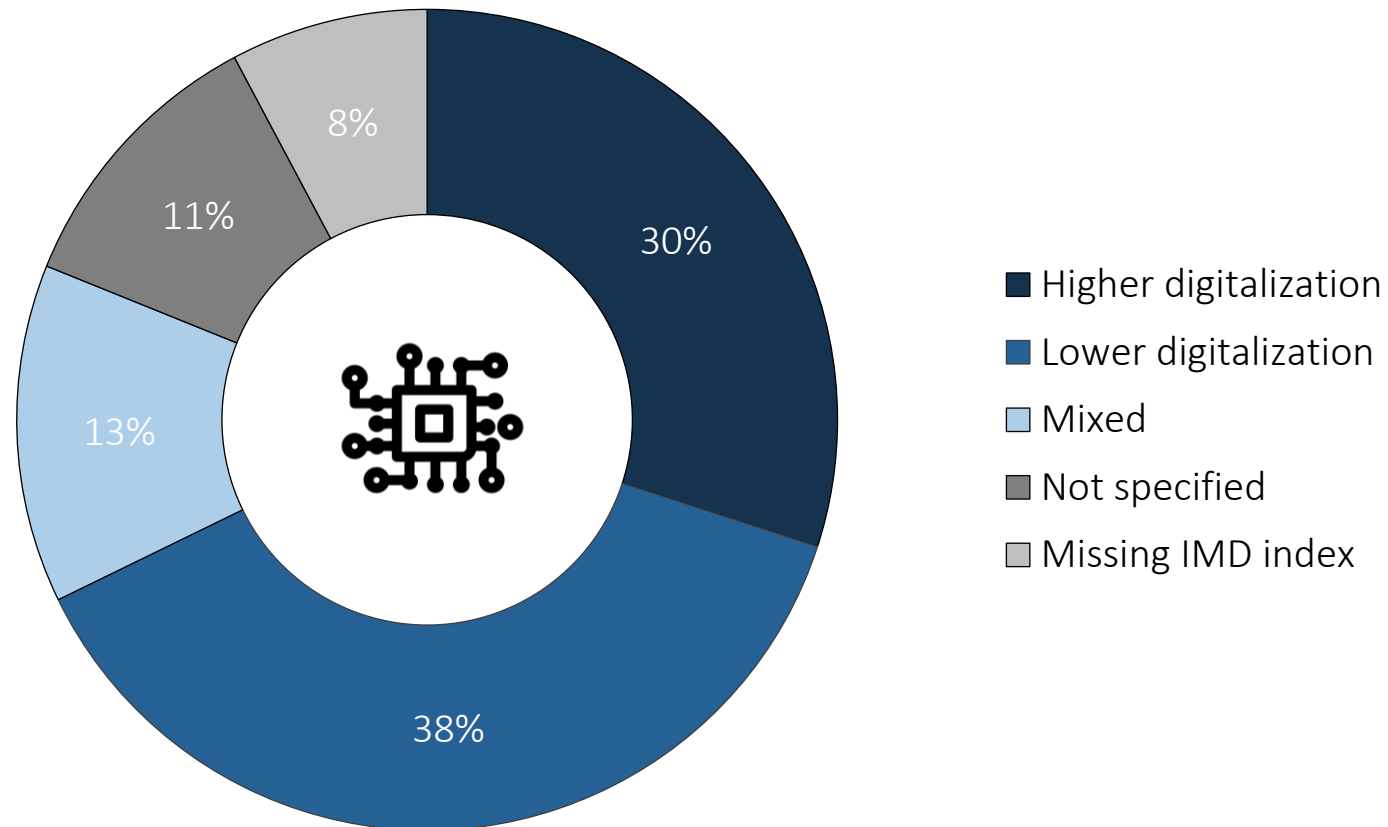
The demographic characteristics of the sample

The number of papers discussing the barriers of DT has increased dynamically. While there were only 1-1 papers till 2018, from 2019 on the trend becomes exponential. The 90 papers spread over 45 different journals.



The demographic characteristics of the sample

30% of the papers use empirical data from a country with higher digital competitiveness, 38% from a lower country, 13% is mixed, 11% is not specified, and IMD does not index 8%.



Barriers to digital transformation

To grasp the types of barriers we built a framework to be able to categorise the potential barriers. Since our objective is to see the barriers at multiple levels, the levels of individual, company, supply chain and country were used.

RQ1: What are the most frequent barriers to DT?

Barriers Levels	Direction	Resources					Cooperation between resources	Perspectives				Other
		Technological resource		Human resources				Financial perspective	Legal perspective	Material perspective	Information perspective	
	Strategy (policies, directions, goals, measures)	Technology (current level of technology)	Integration and infrastructure	Leadership	Human resources (knowledge and skills)	Culture (behaviour, attitude)	Cooperation (vendors or customers, between people)	Economic / financial	Legal (laws, regulations)	Process / project execution	Data management / security	Other
Individual	3	0	0	15	17	33	1	0	0	0	0	0
Company	61	32	43	38	57	44	12	71	9	23	45	1
Group of companies	10	7	16	2	8	15	33	10	3	2	11	6
Country	19	3	18	0	22	2	2	15	24	0	3	2

Number of papers

Thematic direction of papers

The differences were statistically significant in 7 out of 12 barrier categories. They do not differ significantly in four barrier categories: Strategy, Culture, Economic and financial issues, and Human resources, to which they all assign high importance.

RQ2: What is the thematic direction of papers?

Differences by levels

	Country	Group of companies	Company	Individual	Upper-middle income country	Higher digital competitiveness
Cluster 1	0.65	0.85	0.94	0.59	0.57	0.52
Cluster 2	0.18	0.27	1.00	0.64	0.67	0.63
Cluster 3	0.83	0.33	0.92	0.46	0.47	0.38
Cluster 4	0.29	0.62	1.00	0.48	0.44	0.27

Significant differences marked with bold

Differences by areas

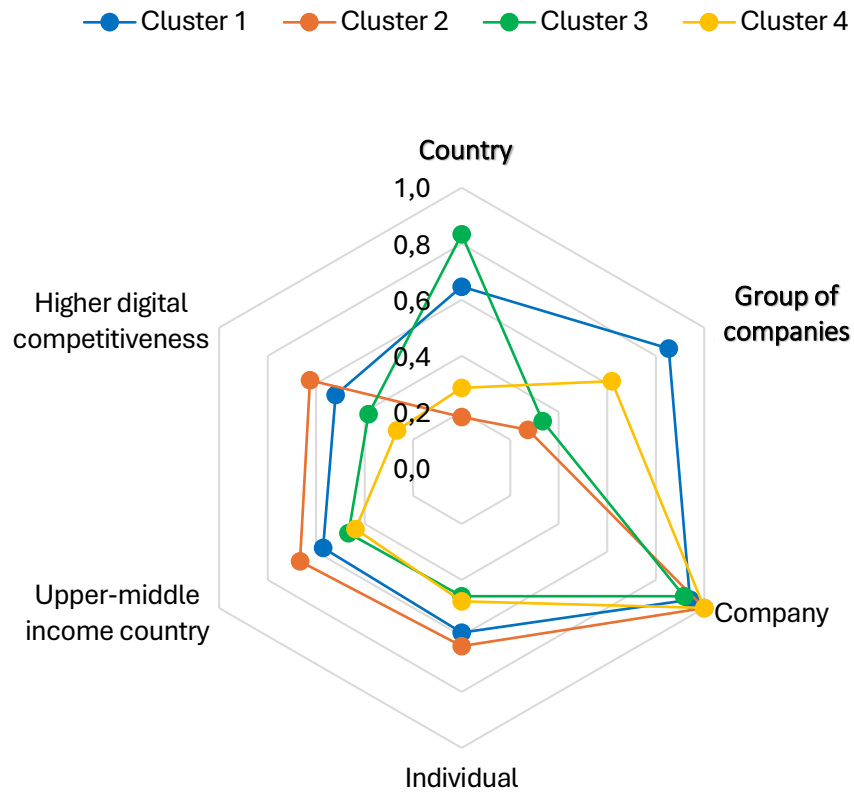
	Strategy	Culture	Economic, financial	Human resources	Other	Cooperation	Data management	Integration and infrastructure	Leadership	Technology	Legal	Process
6 (34)	0.80	0.74	0.83	0.79	0.12	0.79	0.71	0.74	0.76	0.79	0.24	0.18
56 (11)	0.55	0.73	0.82	0.82	0.00	0.55	0.00	0.00	0.09	0.09	0.00	0.18
48 (24)	0.79	0.63	0.96	0.83	0.13	0.17	0.67	0.79	0.13	0.17	0.75	0.04
67 (21)	0.76	0.81	0.81	0.81	0.10	0.29	0.62	0.76	0.76	0.24	0.19	0.71

Significant differences marked with bold

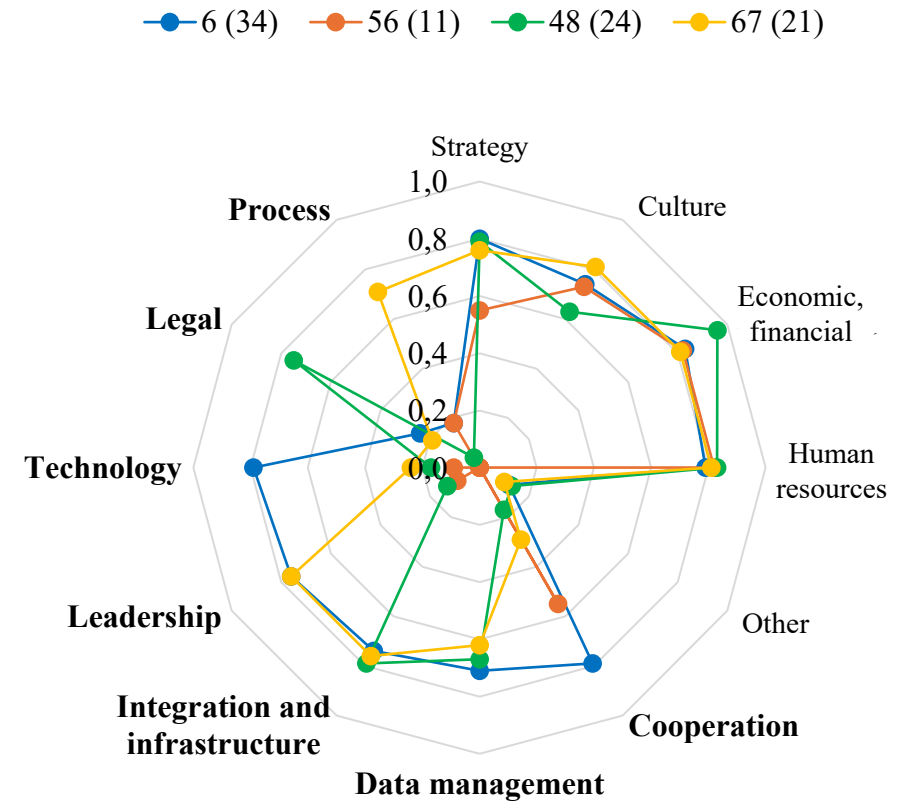
Thematic direction of papers

Cluster 2 emphasizes Cooperation. The other three clusters put a similar emphasis on Data management and on Integration and infrastructure. Cluster 3 is the only cluster with a significant load on the Legal barrier category.

RQ2: What is the thematic direction of papers?



Significant differences marked with bold

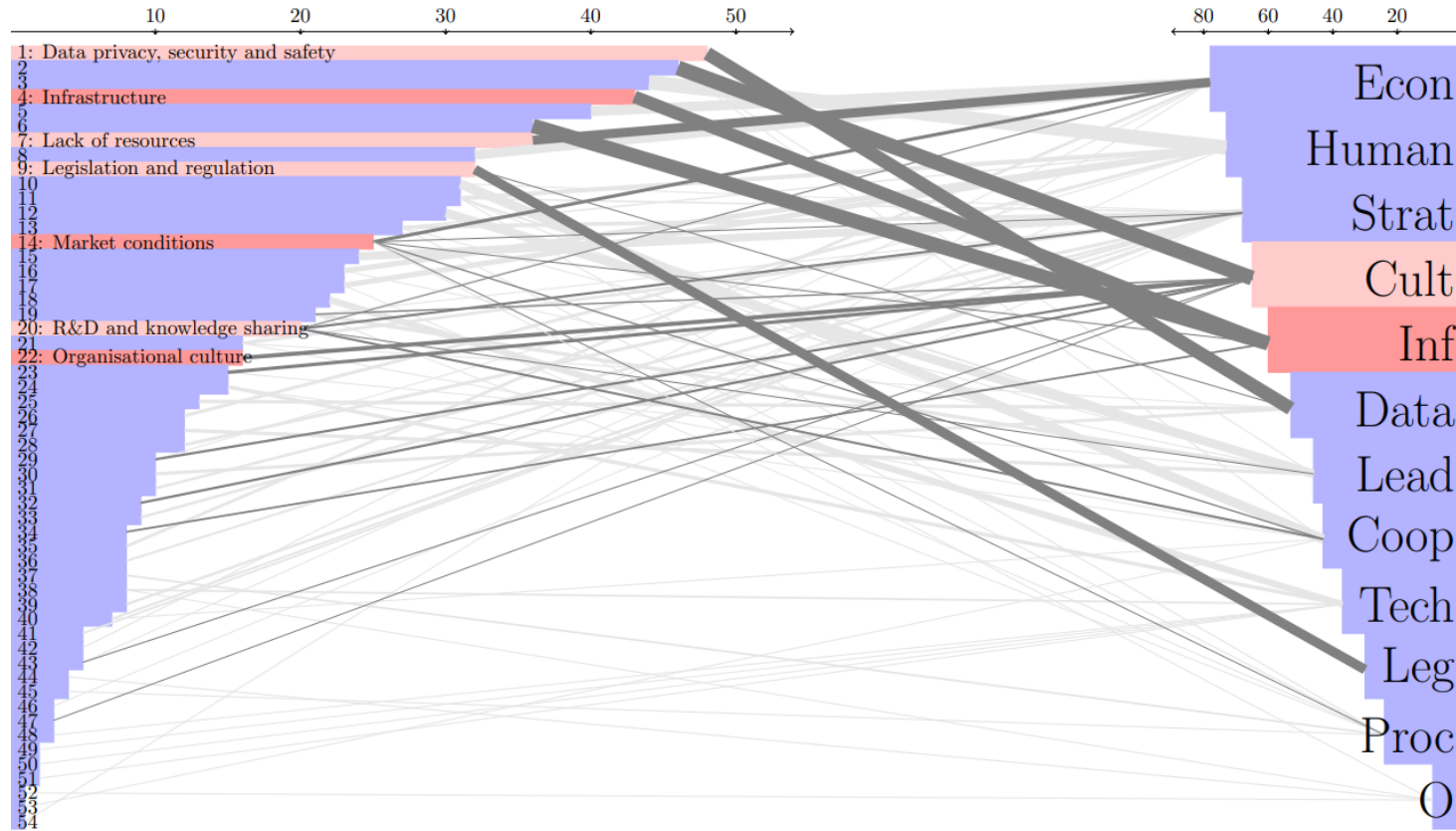


Significant differences marked with bold

Differences between countries with higher and lower digital competitiveness

While less digitalized countries face more challenges in these barrier categories, our results suggest that most barrier categories are similar across contexts.

RQ3: What are the differences in DT barriers between countries with higher or lower digital competitiveness?



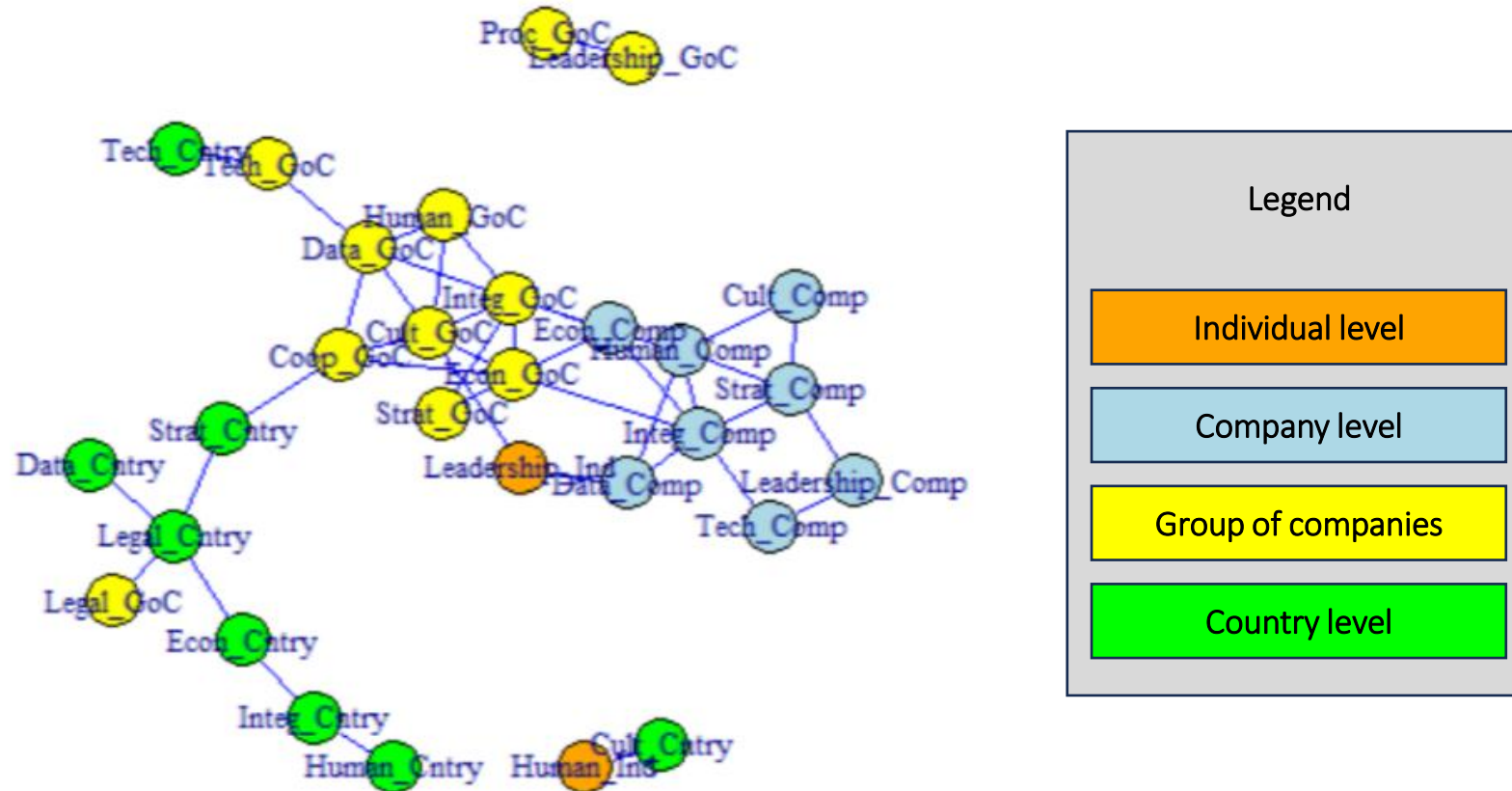
Only 'Integration and infrastructure' shows a significant difference at 0.05 p-level (low-digi: 0.79 and high-digi: 0.48), and 'Culture' (0.85, 0.63) differs at the 0.1 p-level.

Legend: red bar: significant difference at the 0.05 p-level (test of independence); orange bar: at the 0.1 p-level, blue: no difference; link thickness: number of items linking overall barriers to barrier categories

Barrier categories' interplay

We explored the interplay of barrier categories at each level and the interface barrier categories bridging levels using the test of independence methodology, considering only those pairs where we found a significant difference from the test.

RQ4: How can we describe the interplay of barrier categories at each level and what are the barrier categories that play the role of interface by bridging levels?



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Our framework is wide enough to collect all the potential barriers to digital transformation. Providing a full and structured picture of barriers makes it easier for companies and governmental policies to be prepared.



The **most frequent barriers are economic, strategic, and skills-related**. These barriers are not new and not surprising. However, relying on a meta-analysis, using the results of 90 papers, their power is stronger.



Minor differences between the countries with higher and lower digital competitiveness, which goes against previous findings. The **most influential difference is infrastructure**, which was not emphasized in the literature.



Company and group of companies are levels, where the **barrier categories are strongly connected to each other**, showing the focus of the papers mainly on one level. Nevertheless, the connecting role of leadership is visible.

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Thank you for your attention!

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Appendix