



Technology adoption and digital maturity in the conformity assessment industry: Empirical evidence from an international study

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ABSTRACT

Technological innovation and digitalization are transforming industries and organizations worldwide. Digital Maturity Models often serve as a reference point to monitor the digitalization progression through prescribed stages. Yet, little is still understood about (i) how a digital maturity model should be designed and deployed in a specific industry setting and (ii) the association between digital maturity and technology adoption. Building on extant literature and extensive interviews with industry experts, we first develop a digital maturity model in the context of the conformity assessment industry (a globally regulated industry responsible for assessing compliance of organizations with standards and regulations). Second, we implement the model and conduct a survey across 1447 organizations in 15 countries. Our findings reveal that the digital transformation journey of the industry progresses along five stages of maturity (with most organizations in the early/intermediate stages of digital maturity) with distinctive patterns of technical and managerial practices across all stages. Adoption of technologies is (unsurprisingly) associated with higher digital maturity levels - albeit that association does not hold for complex technologies (such as Blockchain) and is impacted by country specifics (measured by the Digital Skills Gap Index). Our study provides insights into digital maturity and the adoption of technologies in an institutional environment that is highly regulated and conservative, in which high integrity of service provision is primary, and digitalization is a secondary focus of organizations.

1. Introduction

While the adoption of emerging digital technologies offers new opportunities for creating value in organizations [1], it also creates disruptions requiring organizations to adopt and develop new technical and managerial capabilities [2–4]. Digital Maturity Models (DMMs) are often used as a reference point to conceptualize digitalization ‘pathways’ [5,6]. DMMs typically include several dimensions and define key stages in digitalization [7,8]. However, digitalization is unique to any given organization – depending on its industry setting (i.e., practices of dominant actors) and its country setting (i.e., availability of staff with adequate skills) [9].

The conformity assessment industry is a good example. It is responsible for assessing the compliance of organizations with standards and regulations [10]. The industry is globally regulated, and the adoption of any new managerial practices (such as the use of new technologies) needs to adhere to specific international regulations and standards. On the one hand, such global governance enforces consistent operational practices of the entire sector across the globe. On the other hand, it also constrains the digitalization and adoption of technologies

[11,12]. The conformity assessment industry also has a conservative approach toward digitalization and the adoption of technologies. Driven by the primary purpose of delivering high-integrity services, the need to digitalize was historically seen as secondary, and the industry was described as predominantly ‘analog’ [13]. The COVID-19 pandemic, however, significantly accelerated technology adoption, including advanced technologies like remote sensing, Blockchain, and AI [14,15]. Even though the sector could be considered global, individual organizations tend to employ local staff and also rely on local quality infrastructure. The unique organizational, industry, and country settings (such as those observed in the conformity assessment industry) bring to the forefront an important question: How can DMMs be developed and deployed in a specific setting to explore the link between digital maturity and technology adoption? Existing DMMs often show substantial shortcomings. For example, the existing literature portrays DMMs as not empirically grounded [3] or lacking theoretical underpinnings [16]. At the same time, DMMs play an important role in assessing the progression towards digitalization. Such incongruence between the need for DMMs and their development is intriguing. To address this problem, we investigate two research questions.

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First, *how should a DMM be designed and deployed in a specific industry setting?* We address this question by developing a DMM that is specific to the conformity assessment industry, grounded in previous empirical findings (from various sectors) and underpinned by management theories (resource-based view and dynamic capability perspective) [17,18]. Our model is based on an extensive literature review (a total of 140 DMMs were reviewed) and validated by industry and academic experts (13 considered industry experts were involved in the design). The model provides a platform for empirical investigation in the industry and allows us to describe the maturity levels of the organizations and the countries in which they operate. Second, we address the relationship between digital maturity and technology adoption, which necessitates further exploration. To address these gaps, we have conducted a survey of 1447 organizations from the conformity assessment industry across 15 countries - allowing us to gain insights into typical paths toward digital maturity [7,19,20] and draw conclusions about the association between digital maturity and technology adoption.

In addressing these two research questions, we make a threefold contribution. First, by developing and empirically implementing a tailored digital maturity model, we contribute to the body of both conceptual and empirical research in the digitalization domain by providing the pathway to the development of a digital maturity model and its deployment in the industry. Previous studies have developed generic DMMs without considering the context [6,19]. Second, we determine patterns of technical and managerial practices associated with the five stages of digital maturity. The findings empirically describe the pathways of digitalization - highlighting the effects of organizational goals/expectations, barriers, and benefits. A cross-country comparison shows that each country's Digital Skills Gap Index (DSGI score) affects digitalization. These findings enhance the literature by providing further insights into the role of organizational practices and country effects on digitalization. Third, we confirm a link between digital maturity and the adoption of technologies and identify key explanatory variables. In line with the literature [6], we demonstrate that the adoption of technologies is (unsurprisingly) associated with higher digital maturity levels in organizations - albeit that association does not hold for complex technologies (such as Blockchain).

In practical terms, our study is the first to comprehensively explore the status of digital transformation in the conformity assessment sector, specifically exploring the development and deployment of a DMM and exploring the link between technology adoption and digital maturity. The remainder of this article proceeds as follows: First, we present the theoretical background of digital transformation and maturity models. We then introduce the methods and data collection for developing and implementing our maturity model. Consequently, we present and discuss our DMM and the results of our comparative and regression analyses. Finally, our findings are summarized, and conclusions are drawn.

2. Literature review

2.1. Digital maturity and digital maturity models

Digital transformation is driven by the rapid emergence and adoption of digital technologies such as artificial intelligence, cloud computing, Blockchain, and the Internet of Things, allowing organizations to transform business models and generate competitive advantage [2,20]. However, to exploit the opportunities associated with technology adoption and to meet the digital expectations of customers, employees, and partners, an "ongoing process of adoption to a significantly changing digital landscape" [21] is needed. The status of a company's digital transformation - defined as digital maturity - comprises both technical and managerial aspects [22]. To account for the increasingly rapid and continuous changes in the digital and business environment and achieve digital maturity [23], "an evolutionary progress in the demonstration of a specific ability or in the accomplishment of a target

from an initial to a desired or normally occurring end stage" [24] is needed, demanding for an actively executed digital transformation process and continuous adaptations [25]. In that sense, the process of digital transformation may never end, and digital maturity can never be achieved completely [2,26].

Maturity models are conceptual models that outline these paths toward maturity [16], allowing one to assess maturity based on a set of criteria [27] and to make an organization's progress toward a target state tangible [3,24,27]. Predefined dimensions and related criteria describe fundamental aspects of digital maturity, such as critical success factors, capabilities, resources, and areas of action [7,21,27]. A maturity model further consists of maturity stages (or levels) [28], which allows for characterizing the performance, practices, and evolutionary status quo of the organization in digital transformation [21]. While most studies suggest a linear path to digital maturity, many scholars doubt the validity of such concepts, arguing that digital transformation is context-specific and can take idiosyncratic paths [3].

Our literature review (see section 3.1) has shown that there is no universal Digital Maturity Model (DMM) but rather a wide variety and heterogeneity of models. We have identified 140 different DMMs, which vastly differ in terms of the industry concerned, the scope, specific topic areas, and covered dimensions centered around predominantly internal foci [22], such as an organization's institutional, organizational, and/or technical capabilities [29]. Notably, these models feature a variety of dimensions, differing with respect to the thematic aspects they reflect, but also regarding the number of those included in the model. Table 1 displays the most frequently used dimensions in the identified DMMs, illustrating the scope of aspects that are critical for a successful transformation. Also, the number of maturity stages that organizations can achieve varies greatly. Strikingly, only very few scholarly works exist that comprise not only a DMM description but also an empirical implementation of it (see e.g. Ref. [7]).

Only little documentation is available on how to develop such a model "theoretically sound, rigorously tested and widely accepted" [27]. Many available models are used in practice-oriented literature and consultancies to support managerial decision-making, providing definitions of archetypes along defined scales of maturity, mostly linear paths [3] from the lowest to the highest maturity level [29].

However, the economic and management literature provides many theories that have helped to improve our understanding of innovation, technology adoption, and digital transformation, allowing us to capture determinants for digital maturity. Helpful theoretical frameworks range, e.g., from path-dependency to evolutionary theory, organizational learning, disruptive innovation theory, or the technology-organization-environment (TOE) framework [16]. Such theories and frameworks can inform and guide the design of maturity models [30]. Since maturity models are designed to assess an organization's digitalization capabilities, dynamic capabilities theory and the resource-based view provide a rich theoretical foundation. Considering that digitalization goes beyond a mere technological perspective, a maturity assessment needs to consider strategic, organizational, managerial, and cultural stakes as well, including processes, resources, capabilities, and skills [22,31]. In a holistic approach, this means reflecting both the internal and external perspectives of the organization [21]. Introducing digital technologies alone does not make an organization digital [2,25]. The value of technology comes from the exploitation of business opportunities and doing

Table 1
Most frequently used dimensions in the 140 DMMs from our literature review.

Dimension	Number of DMM	Dimension	Number of DMMs
1. Strategy	46	6. Process	28
2. Technology	42	7. People	26
3. Customers	34	8. Products	24
4. Culture	33	9. Operations	19
5. Organization	30	10. Information	18

Table 2
Composition of the sample.

Type of CA activity provided	Organization size		
Testing laboratory	56 %	<10 employees	35 %
Certification body	26 %	10-49 employees	40 %
Calibration laboratory	21 %	50-249 employees	16 %
Inspection body	20 %	Over 250 employees,	8 %
Medical laboratory	6 %	I do not know	1 %
All other	6 %		

Table 3
Regression Analysis: Correlations of the use of digital technologies and Overall Digital Maturity.

Variables	(1)	(2)
	MaturityScore	MaturityScore
All techn.	–	0.423*** (0.0273)
Mobile tech.	0.0889***(0.0172)	–
Big Data	0.0591***(0.0165)	–
AI	0.0474***(0.0238)	–
Cloud c. techn.	0.0587***(0.0148)	–
Digit. Twins	0.0380***(0.0171)	–
RFID	–0.0432***(0.0194)	–
Remote Sen.	0.0739***(0.0178)	–
Blockch. techn.	–0.0184(0.0248)	–
Drones	–0.0175(0.0210)	–
IoT	0.0683****(0.0210)	–
Enhanc. A./R.	0.00423(0.0180)	–
Embed. IT sys.	0.0747****(0.0151)	–
Vir. Reality	0.00347(0.0225)	–
Constant	2.322****(0.0549)	2.600****(0.0341)
Observations	1104	1193
R-squared	0.287	0.205

business differently enabled by technology [32]. Building on accordant capabilities, digitally mature organizations feature, e.g., a dedicated strategy and common understanding of leveraging technologies to change the way they do business [31]. They adopt “structures, practices, values, and beliefs that help organizations to thrive in an increasingly digital environment” [2].

2.2. Digital transformation and the conformity assessment industry

Digital transformation is a key topic for conformity assessment (CA). On the one hand, the market success of new digital products and services requires trust in them. Based on standards, conformity with specified requirements can be demonstrated by CA services, such as certification (i.e., labels) or testing [33]. This specifically concerns cybersecurity: certification based on standards, e.g., management system standards such as ISO/IEC 27001, has been identified and supported by policymakers to tackle privacy and cybersecurity risks associated with digitalization [34]. Furthermore, internationally accepted standards and accordant CA services can contribute to transparency and trustworthiness regarding the safety, security, and provenance of new digital technologies and applications, e.g., based on AI, thus supporting market acceptance [35]. On the other hand, CABs also need to adopt digital technologies for their own processes and organization. This is not only important to achieve efficiency gains or exploit new business opportunities but, as previous research has shown, also in order to be resilient in times of crises – an important feature especially for the CA industry. Previous research has revealed increased digital technology adoption triggered by the COVID-19 pandemic: Castka et al. [36], e.g., found certification bodies in the context of voluntary sustainability standards to increasingly use remote auditing and ICT with the start of the COVID-19 pandemic. However, a previous (practice-oriented) study on digital maturity in various sectors found that organizations in CA still need to catch up compared to other industries [37] – including their own customers’ industries.

3. Methods and data

This section elaborates on the steps followed to design and empirically implement a model to assess the digital maturity of the conformity assessment (CA) industry (Fig. 1). In the first place, the **scope** of the model i.e. the addressed domain, needs to be determined. In our study we addressed the conformity assessment industry at large, covering organizations with commercial, academic, and public backgrounds performing diverse types of CA. The **design** follows the St. Gallen model of digital maturity proposed by Berghaus and Back [7] and Friedel and Back [28]. To **collect the data**, we designed an online questionnaire for the CA industry, distributing it with the support of national accreditation bodies. The **data analysis** encompasses both the calculation of the digital maturity scores following the St. Gallen model [28,38] and regression analysis to identify the relationships between digital maturity and technology adoption, as well as other digitalization variables from our survey.

3.1. Design

To build an adequate Digital Maturity Model (DMM), we first conducted an extensive literature review of DMMs. Using search strings centered around digital maturity and readiness in relevant databases (i. e., Scopus, Web of Science), we identified relevant articles and additional literature through forward and backward referencing [39] and citations in these studies. In total, we reviewed 140 DMMs from different domains, which we assessed regarding their scope, extent, and structure, including the most commonly represented dimensions (see Table 1). However, a thorough description and explanation of how the dimensions have been derived and selected is rare in the literature. Only a few studies provide insights into their theoretical foundation. Based on the first insights from our literature review, we built on and consulted innovation, technology adoption, and transformation management literature to capture the most relevant success factors, barriers, and determinants of digital maturity. As outlined by De Bruin et al. [27], such an approach helps to identify what needs to be measured and how.

Furthermore, we considered the distinctive characteristics of context to capture determinants and preconditions of digital technology adoption in the Conformity Assessment industry and the accordant maturity. Many dimensions identified in our DMM review might be understood as dynamic capabilities [40–42] despite scarce research on their relationship with digital transformation [23]. However, representing abilities and skills to generate, identify, and analyze new knowledge in an organization to stay competitive and innovative [23,25], dynamic capabilities can be deemed critical for transformation. These capabilities encompass various aspects such as cross-functional **collaboration**, **innovation** capacity, or market/customer orientation [23,25]. Additionally, aspects such as cultivating an open risk **culture** [23,25,43] have been identified as specifically important in digital transformation contexts [44]. Building on the theoretical literature as well as on previous studies, dynamic capabilities for digital transformation readiness have been included in our DMM, encompassing dimensions such as Customers, Culture, Innovation and Cooperation. In that way, it accounts for the importance of an organization’s ability to adapt and innovate in dynamic environments, incorporating capabilities that are expected to facilitate the adoption of digital technologies [23]. The role of dynamic capabilities is also ascertained by the disruptive innovation theory that helps understand why companies succeed or fail in light of disruptive innovation, such as digital technologies, considering



Fig. 1. Digital maturity model development phases based on De Bruin et al. (2005).

adequate resource allocation, **skills**, **customer** competence, and networks [45].

Dynamic capabilities theory can help explain why and how organizations adjust resources to sustain competitive advantage in changing contexts. Creating capabilities depends on adequate configuration and reconfiguration of resources [42,45]. Thus, resources - including physical, financial, human, and organizational - play an important role in a successful digital transformation. We draw from the resource-based view (RBV) [46], recognizing the relevant contribution of these resources to organizational success and their facilitation of digital transformation through innovation. Thus, we integrate the resource perspective across various dimensions, such as Organization and Information Technology. These capabilities and resources allow organizations not only to recognize but also to adapt to **change** through innovation [47]. The lack of some resources or dynamic capabilities may impede an organization from adopting or developing digital technologies and digitally transforming [48].

The design of the DMM was also informed by business and management literature that heavily supports the role of business **strategy** in an organization's ability to digitally transform [44]. Accordingly, the development and implementation of a clear digital strategy and leaders who foster a culture of change and risk-taking are found crucial [44].

To expand the perspective beyond the internal view of the organization, the Technology-Organization-Environment (TOE) Framework provides additional contextual determinants of transformation decisions to be considered [7,49]. Besides the characteristics and resources of the organization, it also covers external drivers and environmental context, including e.g. relevant digital and **information technologies** (IT) [50]. Though often neglected in analyses, technologies play a crucial enabling role in responding to disruptive innovations, fundamentally transforming business processes, products, services, and relationships [45]. Building IT capability requires combining IT infrastructure, human IT skills, intangibles, and other organization-specific resources [51]. This illustrates the interaction of different theoretical concepts along relevant dimensions of digital maturity.

We used the analysis of existing DMMs, as well as the further literature and theoretical frameworks on innovation and transformation, as a solid foundation to deduct items that reflect the necessary capabilities, resources, external factors, and barriers to drive digital transformation successfully.

Accordingly, our DMM comprises seven key dimensions that represent critical success factors, barriers, resources, and capabilities that help grasp the digital maturity of organizations (see Fig. 2): (1) Strategy, (2) Information Technology & Process Digitalization, (3) Customers, (4) Culture and Expertise, (5) Organization and Change Management, (6) Innovation, and (7) Cooperation. Each dimension consists of four to six items (in total, 37 items - included in Appendix) describing various aspects of the respective dimension, with different degrees of difficulty of

attainment.

Following the design of our DMM based on the thorough review of the theoretical and management literature and existing DMMs, we tested its suitability and further enhanced it with the help of expert interviews (see section 3.2).

3.2. Data collection

The basis for assessing the digital maturity of the CA industry was a broader online survey with 40 questions covering multiple facets of digital transformation in the conformity assessment industry. The questions covered the following aspects: 1) the current status of digitalization and digital maturity of the CA industry (based on the DMM introduced in Section 3.1); 2) the drivers, benefits, and barriers related to digital transformation, and 3) the digital technologies currently in use in the surveyed organizations.

During and after drafting the survey, we conducted semi-structured interviews with 13 CA experts from the industry and academia to identify and verify the most relevant factors of digitalization in the CA industry. The survey questions were designed as multiple-choice, yes/no, or 5-point Likert scale questions, e.g., 1 for "not important" and 5 for "very important." To ensure the validity and reliability of the questionnaire, we conducted an additional pre-test with seven representatives from CABs and industry associations, using the cognitive technique of the "Think-Aloud Method" [52]. Following the experts' comments and reactions, we adapted the survey questions accordingly. To gather the data and ask the organizations to participate, we partnered with national or regional accreditation bodies,¹ which disseminated the online survey among their member CABs. In each country, the survey was administered for an average of 6 weeks, from December 2021 to November 2022.

3.3. Data analysis

3.3.1. Calculation of digital maturity scores

To identify the different stages of digital maturity within the CA industry, we adopted the methodological approach proposed by Berghaus and Back [7] and Friedel and Back [28]. As shown in Fig. 3, this approach included a self-assessment of digital maturity by the CABs and, consequently, the calculation of the digital maturity scores. More specifically, by answering the survey questions related to the seven dimensions, the items were populated through a self-assessment by the participants on a 5-point Likert scale, indicating whether the specific items were fulfilled by their organization.

Based on the self-assessment, the digital maturity scores of the participating CABs were calculated following the St. Gallen model of digital maturity [7,28]. The overall digital maturity score represents the mean average of an organization's point maturity and cluster maturity score. First, we calculated the point maturity scores for each organization. This was done by first calculating the difficulty of attainment for each item (also called metric) in the seven maturity model dimensions based on the Rasch Algorithm, using the statistical software *Winsteps Rasch* (A metric score of "0" represents the mean difficulty). A negative metric indicates that the item is easy to achieve, while a positive metric indicates that the item is difficult to achieve. Subsequently, we calculated the point maturity scores as the sum of the individual difficulty levels multiplied by the actual scores achieved by each organization (on a scale from "1: I do not agree at all" to "5: I fully agree"). However, the point maturity score adds up the overall fulfillment of items out of the total points achievable regardless of their difficulty levels. For instance, an organization can attain the highest points possible in a difficult item but a low score in a relatively easy item. Yet, more difficult items are

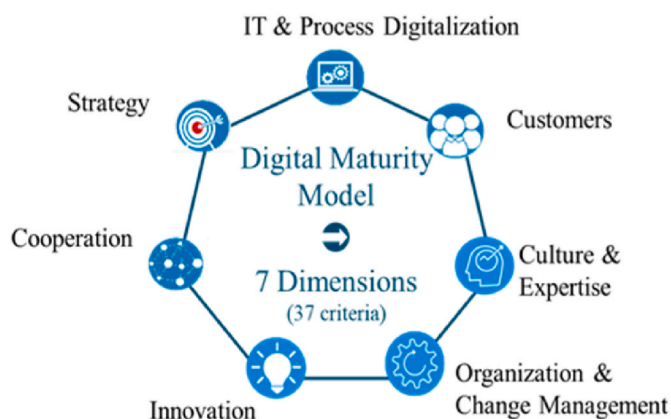


Fig. 2. Digital maturity model dimensions.

¹ An accreditation body (AB) is a formal, third party that recognizes the technical competence of CABs to deliver conformity assessment services.

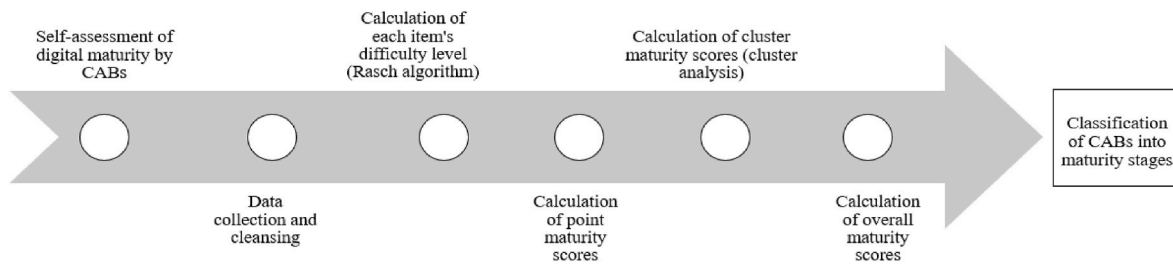


Fig. 3. Methodological steps.

more weighted; thus, their fulfillment generates higher point maturity scores.

In contrast, the cluster maturity score systematically structures the fulfillments according to the difficulty levels for each item. The more organizations have fulfilled a particular item, the easier it is rated. Accordingly, the easiest items are clustered in maturity cluster 1 (beginner level), and the most difficult items form the highest maturity cluster 5 (expert level) (Fig. 4) [22]. Thus, the cluster maturity score refers to the sequential fulfillment of items across different maturity clusters. An organization may reach a higher cluster maturity score only when a specific threshold value is achieved in the previous, easier cluster.

Ultimately, we calculated the overall maturity score as the point maturity and cluster maturity score average. Due to the metrics, the values are approximately normally distributed. Finally, following the approach of Berghaus and Back [7] and Friedel and Back [28], we classified the surveyed CABs into the five distinctive identified maturity stages.

3.3.2. Regression analysis

Besides the descriptive analysis, we analyzed the effects of general organization-specific characteristics – including their general assessment, motives, impacts, and barriers to digitalization – on digital maturity using regression models (Table 4). To this end, we conducted a standard multiple Ordinary Least Squares (OLS) regression analysis and an additional fixed-effects regression analysis to account for the unobserved heterogeneity in our data by including country-fixed effects (Table 5). As a statistical software, we used Stata 16 [53]. Although all variables are ordinally scaled, we treated them as metric variables [54]. In a separate OLS model, we calculated whether organizations’ use of specific digital technologies is, on average, associated with higher digital maturity levels (Table 3). Due to the presence of heteroscedasticity in the data, we used robust standard errors in all regressions.

4. Results

4.1. Sample description

In total, we collected valid responses from 1447 organizations from 15 countries (dark blue) and one region (dark grey) (Fig. 5) that participated in the survey (=15 % average response rate).



Fig. 4. Digital maturity model: Stages.

82 % of the participating organizations were private companies, 12 % were public bodies, and the remaining 6 % were research institutions. Most (56 %) operate as testing laboratories, and 75 % are small-sized organizations (Table 2).

The survey reveals that many organizations in the CA industry have just started to address digitalization (37 %), and only 18 % have already integrated it across the entire organization. By far, the main focus area is the optimization of internal processes (81 % of all organizations), followed by internal and external communication. The least in focus is the adaptation of the business model through digital technologies (14 % on average, yet with considerable country differences). In the following sections, we will present the findings on digital maturity and technology use in more detail.

4.2. Digital maturity of the CA industry

Drawing from the survey data and our methodology (Section 3.3.1), we calculated the digital maturity scores (DMS) of the surveyed organizations in each participating country and region. Analyzing the items fulfilled in each stage by most participating organizations indicates their difficulty, prioritization, and possible sequence of digital transformation activities [7]. Accordingly, items fulfilled in lower stages (thus by many organizations) are basic groundwork, while items in higher stages indicate a higher degree of difficulty, with advanced activities that build on previous ones. As shown in Fig. 6, the resulting maturity scores are ranked from 2.55 (West Africa) to 3.30 (United Kingdom), with an international average DMS of 3.03.

Based on this self-assessment, we calculated the achievements across the seven digital maturity dimensions (Fig. 7, left side).

The two most advanced dimensions are “Culture & Expertise” and “Information Technology & Process Digitalization,” with the latter dimension being attributed the highest relevance by participants. Here, the organizations state, e.g., that important, relevant technologies and their impact are known, and IT investments are made. Furthermore, their IT department can ensure the use of digital technologies and employees are aware of IT security issues.

In contrast, the dimension “Organization & Change Management” has the lowest average fulfilment – despite a rather high attributed importance. Based on these individual assessments along the seven dimensions, we calculated the individual maturity scores for all participants (see 3.3), as well as the final digital maturity levels. As shown in Fig. 7 (right side), most organizations across all countries have reached the intermediate level (stage 3, 46 %), while only 16 % are already in stage 4 and 2 % in stage 5. However, more organizations are still at lower levels (5 % at beginner level 1 and 31 % at level 2).

Following the clustering results, we observe distinct patterns of digital maturity along the five maturity stages. Organizations in **stage 1** (“Beginners”) already assign digitalization a central role in their overall strategy and are open to digital transformation, considering it as a new source of value creation. Furthermore, they are aware of IT security and work on it. To evolve into **stage 2** of digital maturity, we observe a strong focus on *information technology and process digitalization*: organizations invest in digital technologies and have networked processes and

Table 4
Descriptive statistics.

	N	Mean	Sd	p50	Min	Max	Description
MaturityScore	1286	3.01	0.86	3	1	5	Overall Maturity Score (from 1 to 5)
Mobile tech.	1320	2.74	1.57	4	-1	4	Mobile technologies, devices, and services
Big Data	1308	1.12	1.72	1	-1	4	Big Data and Big Data Analytics
AI	1307	0.58	1.31	0	-1	4	Artificial Intelligence (AI) and machine
Cloudc. techn.	1311	2.19	1.77	2	-1	4	Cloud computing technologies
Digit. Twins	1304	0.21	1.47	0	-1	4	Digital twins
RFID	1308	0.33	1.35	0	-1	4	Radio Frequency Identification (RFID)
Remote Sen.	1309	0.61	1.53	0	-1	4	Remote Sensing
Blockch. techn.	1303	0.1	1.16	0	-1	4	Blockchain Technology
Drones	1307	0.36	1.21	0	-1	4	Drones
IoT	1297	0.51	1.4	0	-1	4	Overarching Internet of Things (IoT)
Enhanc. A./R.	1296	0.9	1.56	0	-1	4	Enhanced Automation/Robotics
Embed. IT sys.	1296	1.7	1.82	2	-1	4	Embedded IT systems
Vir. Reality	1305	0.35	1.21	0	-1	4	Virtual/Augmented Reality
All techn.	1325	0.92	0.93	0.85	-1	4	All technologies
Intl. CAB	1437	0.19	0.39	0	0	1	International CABs (dummy variable)
Empl. Age	1365	44.25	4.05	47.5	40	55	Employees' average age (from <40 to >55)
Perc. digit.	1387	1.29	0.8	1	-2	2	Perception of digit. for CA industry (-2 to +2)
Digit. agenda	1265	4.56	3.13	3.5	1	10	Time dealing with digit. (<2 to >10 years)
Expect	1214	-0.19	0.9	0	-2	2	Fulfillment of digit. expectations (-2 to +2)
Seaml.	1268	1.32	0.83	1	-2	2	Achieve seamless data flow (motive)
CA cust.	1271	1.1	1.01	1	-2	2	Provide better CA services to customers (-2 +2)
Compl.	1376	0.47	1.18	1	-2	2	Complexity of digit. processes (from -2 to +2)
Time constr.	1373	0.5	1.21	1	-2	2	Time constraints (from -2 to +2)
Internal proc.	1357	1.15	0.99	1	-2	2	Faster internal processes (from -2 to +2)
Cust. satisfc.	1344	0.82	1.05	1	-2	2	Improved customer satisfaction (-2 to +2)
COVID-19	1300	0.76	0.43	1	0	1	Digitalization driven by COVID-19 (dummy v.)
Manuf.	1447	0.38	0.48	0	0	1	Manufacturing industry served (dummy var.)
DSGI	1405	5.9	1.37	5.9	3.9	7.8	Digital Skills Gap Index 2021

Table 5
Regression Analysis (3 models).

Variables	(1)	(2)	(3)
	DMS	DMS with DSGI	DMS with fixed effects
General information about the organizations			
Intl.	0.0760(0.0462)	0.0512(0.0464)	0.0465(0.0464)
Empl. Age	-0.00297 (0.00493)	-0.00559 (0.00514)	-0.00590 (0.00514)
Assessment of digitalization in the organization			
All	0.238***(0.0263)	0.233***(0.0264)	0.242***(0.0269)
Technologies			
Perc. digit.	0.0825*** (0.0264)	0.0865*** (0.0265)	0.0772***(0.0259)
Digit. Agenda	0.0183*** (0.00630)	0.0155** (0.00624)	0.0129*(0.00665)
Goals and Expectations			
Digit. expect.	0.301***(0.0272)	0.288***(0.0279)	0.295***(0.0276)
Seaml.	0.0695*** (0.0264)	0.0703*** (0.0267)	0.0845***(0.0278)
CA cust.	0.101***(0.0219)	0.111***(0.0221)	0.0856***(0.0224)
Barriers			
Compl.	-0.0388** (0.0185)	-0.0435** (0.0187)	-0.0375**(0.0182)
Time constr.	-0.0497*** (0.0179)	-0.0564*** (0.0181)	-0.0476*** (0.0182)
Impacts			
Internal proc.	0.109***(0.0250)	0.104***(0.0258)	0.109***(0.0247)
Cust. satisfc.	0.0749*** (0.0249)	0.0851*** (0.0256)	0.0910***(0.0248)
COVID-19	-0.0287(0.0464)	-0.0600(0.0518)	-0.0801(0.0539)
Manuf.	-0.0540(0.0393)	-0.0579(0.0394)	-0.0464(0.0392)
DSGI	-	0.0385**(0.0179)	-
Constant	2.480***(0.236)	2.400***(0.242)	2.626***(0.256)
Observations	926	907	926
R-squared	0.536	0.535	0.560

IT departments (or external service providers) while the risk of failure is accepted. Most customer interactions occur via digital channels, and changes in customer behavior are analyzed to identify the potential for

digital innovation. Organizations in this stage have adequate staff, collaboration across departments, and skills to transform digitally. At the intermediate digital maturity level (**stage 3**), organizations have a well-documented digital strategy and exploit the latest digital opportunities to automatize routine processes. The development of digital expertise is promoted through targeted training, and digitalization generates competitive advantages for organizations. Digital innovation is driven systematically, and exchanges with external experts create additional digital knowledge.

Stage 4 is centered around *Organization and Change Management*, where organizations have sufficient dedicated resources at their disposal in their day-to-day business to drive digital innovation as well as defined roles, responsibilities, and decision-making processes. Further, they have defined measurable goals for digitalization based on a digital roadmap. The organizations systematically analyze customer needs to develop appropriate digital solutions. To reach the final maturity **stage 5** (i.e., the digital “expert” status), organizations have a digital roadmap and use metrics to monitor its implementation. An “early alert” process is in place to identify relevant digital technologies or business models, and customers are involved in developing new digital innovations. To that end, organizations have a clearly defined innovation process for implementing new ideas for customers and employees. They collaborate effectively with external stakeholders on digital initiatives and maintain an accordant partner network.

4.3. Technology adoption

This section explores the digital technologies and applications that the surveyed organizations have actually adopted or planned to use. To this end, participants were presented with major digital technologies and applications and asked to rate their use or awareness. Fig. 8 displays the relative distributions, illustrating huge differences: While mobile technologies, devices, and services are regularly used in 53 % of organizations (n = 1312) and cloud computing technologies in 40 %, other advanced technologies such as Big Data Analytics (18 %), Enhanced Automation/Robotics (12 %) and Artificial Intelligence (AI, 5 %) are used less frequently. Blockchain technology and Virtual/Augmented

Brazil (n=227)	New Zealand (n=57)
Colombia (n=69)	Peru (n=62)
Croatia (n=44)	Singapore (n=122)
Germany (n= 354)	Spain (n=106)
Ireland (n=29)	The Netherlands (n=80)
Italy (n=114)	United Kingdom (n=57)
Latvia (n=27)	West Africa (n = 42)
Mexico (n=57)	

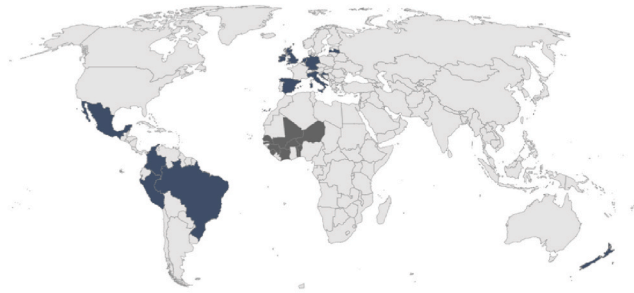


Fig. 5. Overview of countries and regions covered and number of participants.

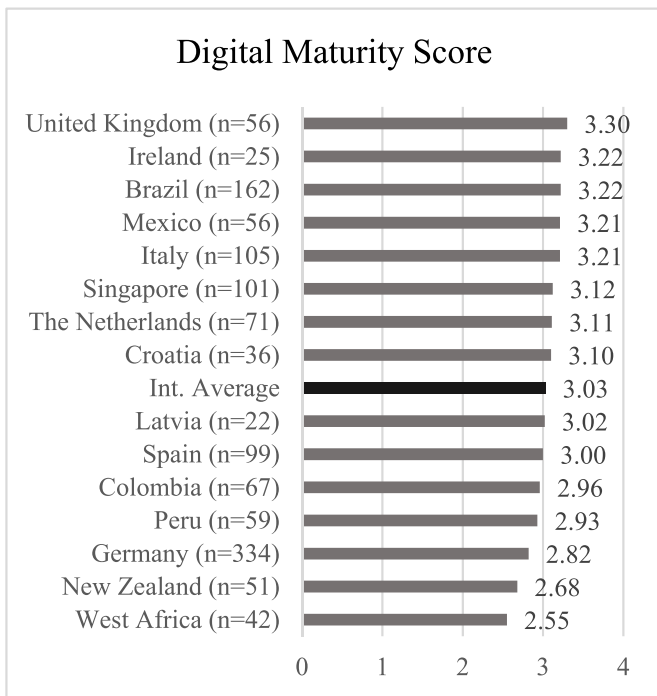


Fig. 6. Country rankings of the Average Digital Maturity Scores.

Reality are the least implemented technologies (3 and 4 %, with 21 and 13 % not knowing the technologies at all, respectively).

These findings highlight that the CA industry is still largely based on traditional (analog) processes. For example, on-site inspections are still prevalent, even though remote inspections would be technically

possible. Fig. 9 further displays a country ranking of the average achieved technology use score, operationalized by attributing point values according to the level of use/awareness (from -1: technology unknown to 4: technology regularly in use).

4.4. Digital maturity and technology adoption: regressions

This section explores the link between digital maturity and technology use in more detail. To this end, we ran OLS regressions to analyze the statistical relationship between digital maturity and technology use (Table 3). In most cases, our results show evidence that more extensive use of digital technologies is, on average, associated with higher digital maturity levels, holding all other variables constant. However, there are also differences across technologies: Basic digital technologies, such as mobile technologies, cloud computing, and embedded IT systems, are positively and significantly associated with digital maturity. In contrast, we find no evidence of significant statistical relationships between more complex digital technologies, such as Enhanced Automation/Robotics or Blockchain technology, and digital maturity.

The significant negative association of Radio Frequency Identification (RFID) with digital maturity score initially seems contradictory. However, in an isolated OLS regression, the regression coefficient shows the expected positive and significant sign. Therefore, weak multicollinearity in the multivariate Model 1 likely explains the issue. In Model 2, the variable “all technologies” represents the average of all digital-technology variables from Model 1 (Table 3). All technologies combined are more strongly and positively associated with higher maturity scores (regression coefficient = 0.423) than the single technology variables in Model 1. Therefore, more extensive technology adoption, e.g., in pilot projects or on a larger scale, is, on average, associated with higher digital maturity, ceteris paribus. In contrast, CABs are, on average, less digitally mature when the technologies are unknown to them or only discussed to be implemented within the next

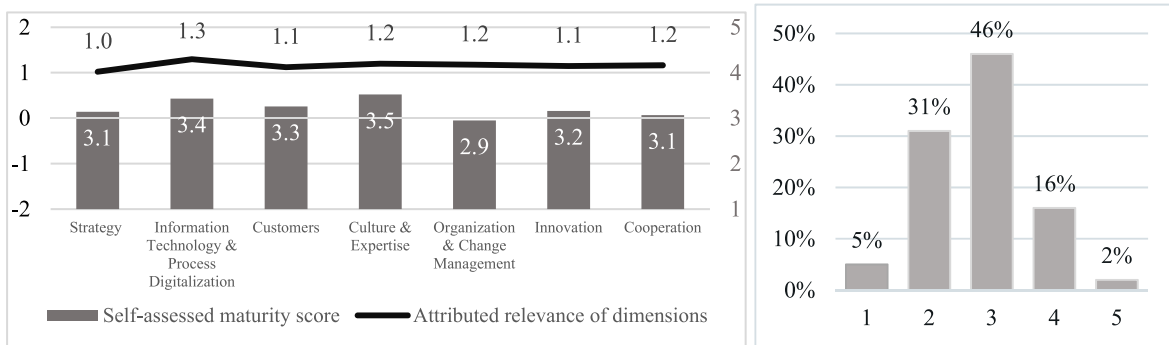


Fig. 7. Average self-assessed maturity score for the seven dimensions of our Digital Maturity Model and attributed relevance of dimensions (left). Distribution of the Overall Digital Maturity Scores of the whole sample (right; from 1 “Beginners” to 5 “Experts”).

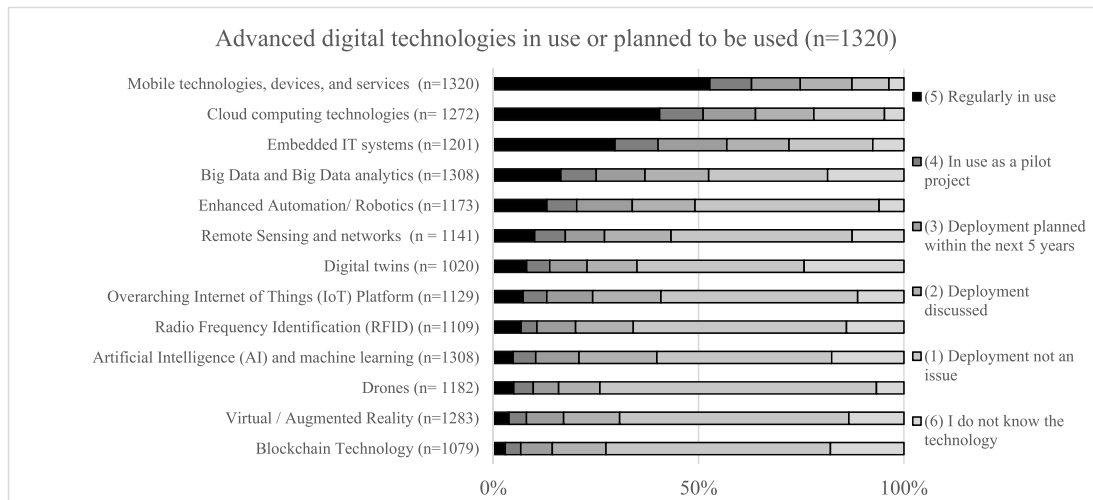


Fig. 8. Technologies used by the surveyed organizations.

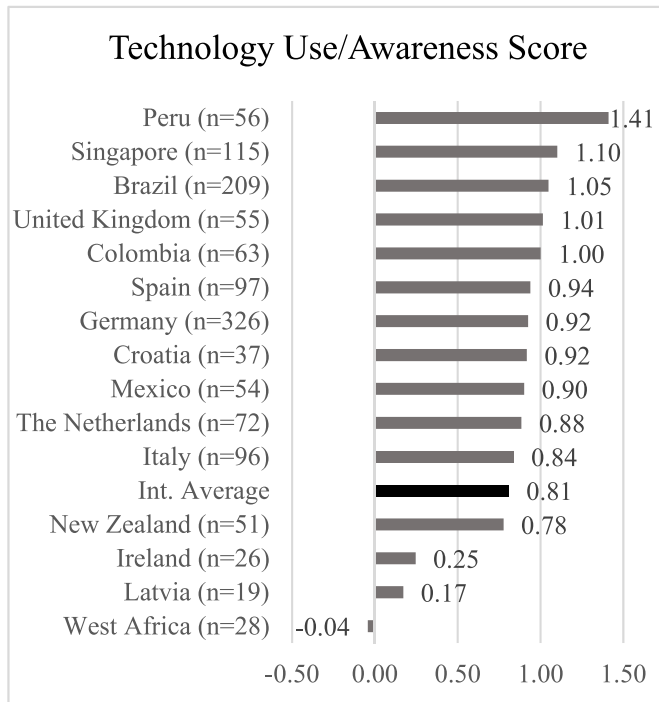


Fig. 9. Average technology use/awareness scores.

five years.

Beyond the above-analyzed technology-use variables, we ran further OLS regressions with an additional set of variables to identify drivers of our dependent variable digital maturity, including: variables capturing the organizations’ demographic characteristics, their general assessment of digitalization, including the adoption of technologies, and the motives and barriers to digital transformation. Moreover, we included the country-specific Digital Skills Gap Index (DSGI) as a further control variable, which operationalizes digital skills levels in a global country ranking [55].

Table 5 depicts the results of the regression analysis, showing the correlations between the explanatory variables (Table 4) and the overall digital maturity scores. In model 1, all explanatory variables (except for the employees’ average age, the COVID-19 variable, and manufacturing) are significantly associated with digital maturity, with the barriers to digitalization showing negative regression coefficients.

Model 2 also explores the statistical relationship between the DSGI and digital maturity but covers fewer observations (the West African region has not been considered since it has no DSGI value). Model 3 includes the same variables and observations as Model 1 but adds the country-fixed effects.

Consistent with Table 3, we find, under *assessment of digitalization in the organization*, more extensive technology adoption to be positively and significantly associated with higher digital maturity across all models (Models 1–3). Furthermore, we observe that respondents who consider digitalization an opportunity and have addressed it at a strategic organizational level are, on average, more digitally mature (Models 1–3).

Regarding the *goals and expectations* for digitalization, we find that the general expectations towards digital transformation (“Digit. expect”) as well as the two leading motives of achieving seamless data flow (“Seaml.”) and providing better customer service (“CA cust.”) are positively and significantly associated with digital maturity across Models 1–3.

In contrast to the motives and drivers, the *barriers* to digitalization show the expected negative effects on the digital maturity scores in Models 1–3. The variables “Complexity of digitalization Processes” (“Compl”) and “Time constraints” (“Time constr.”) are both negatively and significantly associated with digital maturity.

Regarding the *benefits* realized from digitalization, we found that organizations having achieved accelerated internal processes (“Internal proc.”) and enhanced customer satisfaction (“Cust. satisfc.”) are, on average, more digitally mature.

Finally, the results show evidence of the positive effect of a higher DSGI score – as an indicator of the available digitally skilled people in the countries – on organizations’ digital maturity (Model 2), confirming that higher digitalization at a country level trickles down to the digitalization of CABs as economies’ backbone.

Previous literature – and descriptive results from our survey – have found the COVID-19 pandemic to be a driver for digitalization in organizations [36,56–58]. However, our regression analysis does not find a significant relation between the pandemic as a driver for digitalization and actual digital maturity.

5. Discussion

Our findings shed light on the current state of digital transformation in the conformity assessment industry (on a global scale) and the association between digital maturity and the adoption of technologies. Our study reveals that the majority of organizations are at early or intermediate stages of digital maturity, with limited use of advanced digital

technologies. Furthermore, the results of our comparative analysis of digital maturity across countries reveal significant variations among organizations.

Other studies, albeit less focused on particular industries affected by digitalization, have also explored (comparatively) the status of digital transformation and its significance. Brodny et al. [59] found that Central and Eastern European countries lag behind their EU counterparts. Malkowska et al. [60] further investigated the impact of digital transformation on the economy and society in EU countries, focusing on technological development and the digitalization gap. Van Kessel et al. [61] identified cross-country inequalities in Europe regarding internet access and digital skills, requiring increased investment in digital capacity. Similarly, our results identified gaps in digitalization across countries within the conformity assessment industry. This further aligns with the identified positive correlation between the Digital Skill Gaps Index (DSGI) and digital maturity, offering insights into how country-specific factors influence digitalization. This complements the findings from previous research on the reverse positive relationship between digital maturity and the DSGI [62,63].

The digital maturity scores across the seven dimensions of our DMM suggest that digitalization begins with the adoption and use of digital technologies and then evolves into a holistic transformation of the organization [21]. Such a resulting digital maturity pattern aligns with Henriette et al. [31], who characterize digitalization as a disruptive or incremental change process. More precisely, we observe a particular Pattern in the **distribution of different dimensions** along the five stages of digital maturity. For example, the dimension "IT and process digitalization" is a baseline issue already fulfilled by many organizations in the early stages of digital maturity (Stage 2). Nevertheless, the adoption of digital technologies alone is not enough. The technical aspects of digital transformation should be accompanied by complementary managerial capabilities, such as the development of expertise and supportive organizational processes [44]. Notably, strategic orientation towards digital innovations plays a pivotal role in the successful digital transformation of organizations [64–66], which is already a key requirement in early digital maturity stages. Our results suggest that in the intermediate stage of digital maturity, organizations already have a well-documented digital strategy to systematically progress with digitalization [67]. Digital strategy prepares organizations for attaining the next maturity stage 4, which is characterized by clearly defined responsibilities for implementing the **goals** derived from the strategic consideration of digitalization. This is further specified by a defined implementation plan or Digital Roadmap, based on monitoring metrics, in organizations considered as digital experts (final stage 5).

Change management and related activities appear particularly challenging and are primarily concentrated in the later stages of digitalization (stage 4). This means that organizations that can manage change and overcome organizational challenges tend to be more digitally mature overall. This pattern is in line with previous literature, finding that a solid digital foundation in technical terms also requires a good understanding and the appropriate processes to leverage the potential for business advantages [21,68]. Digitally mature organizations have also been characterized by a collaborative and innovative culture [44,68]—accompanied by a growing trend towards networking, collaboration, and forming partnerships with external stakeholders in digital initiatives [69,70]. These partnerships allow organizations to successfully manage digitalization. Our data confirms these findings, showing a focus on collaboration, in particular at later digital maturity stages (stage 5). Digitalization is systematically accelerated by knowledge and capabilities deriving from exchanges with external experts already in the intermediate digital maturity stage (stage 3). This collaboration and accordant partner networks intensify with higher digital maturity stages (i.e., stages 4 and 5) [26,71].

Although organizations that are already in the early stages of digitalization analyze changes in customer behavior to identify the potential for digital solutions, a systematic analysis of customer needs is distinct of

higher digital maturity levels. Our regression analysis confirms that organizations providing better conformity assessment services to customers based on digital technologies and applications are, on average, more digitally mature. This aligns with Saura et al.'s [72] and Kusa et al.'s [20] findings, suggesting that analyzing consumer behavior in the digital era drives organizational digital transformation, including the development of digital business models. According to institutional theory, companies' decisions and actions are driven by the surrounding institutional ecosystem, i.e., companies may feel coercive pressure from competitors or customers to upgrade their services [73,74], thus thriving to become more digitally mature. Especially with the start of the COVID-19 pandemic, a shift in both internal/external communication and delivery of services became necessary for organizations [14,15]. Our study confirms that the motivation for digitalization translates into higher levels of digital maturity. Additionally, taking a resource-based view (RBV) [75,76], digitally improved internal processes are a valuable strategic resource for organizations when providing their services to customers, thus gaining a sustained competitive advantage [77]. Hence, there are internal and external factors for organizations that benefit from digitalization. This trend is reinforced by a growing willingness to adopt external knowledge, depending on the organizational culture's openness to new technologies, change, and transformation [7] - a key factor for adopting digital technologies since the early stages of digital maturity. In the subsequent stages, organizations need to accept the risk of failure in new digital activities, combined with the enhancement of internal digital expertise (e.g., with training).

Our results on the association between digital maturity and technology adoption reveal a complex relationship: while the use of basic digital technologies is generally linked to higher digital maturity levels this association does not hold for more complex technologies like blockchain. Furthermore, it revealed that if technologies are unknown the industry is less digital mature. As argued by Acar et al. [78], the adoption of innovations, such as digital technologies, is met with different types of constraints that prevent innovation from being implemented. The authors show that time constraints are one of the primary barriers to adopting innovations, as our findings confirm as well. Thus, the hesitance and difficulty of organizations to become more digitally mature can be largely explained by their limited time resources and the complexity of their tasks. Additionally, the highly institutionalized (and regulated) nature of the conformity assessment industry presents unique challenges for the digitalization processes. Contrary to previous literature [14,15], our findings did not identify the COVID-19 pandemic as a catalyst for digitalization. This might be due to the kind, scope, and extent of digitalization efforts, which could be limited to the implementation of basic digital technologies (incl., e.g., remote methods), or the efforts have not yet been translated into higher digital maturity.

6. Conclusions

In this study, we conceptualized, developed, and implemented a digital maturity model tailored to the conformity assessment bodies (CABs) to better understand the digital transformation of organizations in this industry. The model is built upon an extensive literature review and interviews, allowing for the identification of relevant success factors, capabilities, and resources to manage digital transformation. With 1447 organizations from 15 countries worldwide participating in the survey, this study provides a broad empirical foundation to validate the developed digital maturity model that other research on digital maturity models often lack [3]. Furthermore, the adoption of specific technologies is linked to the different stages of digital maturity, which was also not realized in other studies. We thus contribute both to the theoretical and empirical literature on digital maturity in the CA industry, which can be the base to be leveraged in other industries.

Our results show that the transformation process is just at the beginning. Most organizations are still in an early/intermediate stage of

digital maturity, focusing on digital technologies, not yet embracing important managerial and strategic advancements, or adapting their innovation and collaboration approaches. However, these are necessary steps to advance digital maturity at a higher level. The adoption of digital technologies is also still at a basic level, centered around mobile and remote technologies, leaving advanced digital technologies and applications like AI, Blockchain, or Big Data Analytics largely unexploited. Our analyses highlight and provide evidence for the link between technology use and digital maturity.

The empirical implementation of the proposed digital maturity model appears to suggest a linear path toward digital maturity, with clearly defined stages and a linear path of transformation. This is oftentimes criticized in digital maturity model literature (e.g., Ref. [3]). We rather emphasize that it is not meant to represent a static template. In fact, the stages differ across countries. Not taking into account context-specific aspects would be an inadequate oversimplification. The model and insights from it, however, do offer some guidance and may well serve as an orientation and source of information for managers and other decision-makers. Driving digital transformation forward is especially important in the CA sector, given its vital role in the economy and sustainable development.

Our findings suggest that a higher digital maturity level is indeed associated with an increased willingness to adopt external knowledge. Therefore, future research might benefit from insights about approaches to open innovation, e.g., considering insights and experiences from technology providers but also integrating customers in the development of digitalized services [72]. A methodological limitation lies in the single source bias, e.g., the inherent subjectivity in the assessment by participants, despite all efforts to keep the items in the dimensions as objective as possible. Here, further data sources should be considered, e.g., public data about the implementation of technologies released on company web pages [79]. A further limitation lies in the small sample sizes in some countries. In addition, although all accredited CABs in the countries were invited, a bias toward those participants who are digital or interested in digitalization can be assumed, while the more digitally immature participants will remain undetected. Here, a non-response analysis would have been appropriate, which was unfortunately not possible because we had no access to the contact details of the targeted organizations. Since the institutional framework relevant to CABs is

quite different between countries, but also within countries, this factor has to be considered because the use of specific technologies is regulated quite differently in the EU compared to other countries. For example, in countries with a quality level of the regulatory framework, standards and the accreditation of certification bodies are less relevant than in emerging economies that have not yet established mature and well-functioning regulations. As technologies and the digital environment constantly change, the dynamic monitoring and further development of the digital maturity model and assessing the adequacy of the items and dimensions should be subject to future research.

CRedit authorship contribution statement

Luana Ladu: Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Data curation, Conceptualization. **Claudia Koch:** Writing – review & editing, Writing – original draft, Visualization, Conceptualization. **Parsa Asna Ashari:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Knut Blind:** Writing – review & editing, Writing – original draft, Conceptualization. **Pavel Castka:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix. Criteria

I Dimension: Strategy

- 1 Digitalization has a central place in our **overall strategy**.
- 2 We **evaluate** new technologies as well as changes in customer behavior to identify potential for digital innovation.
- 3 Our digital strategy is well **documented and communicated**.
- 4 We use **key metrics** to measure the implementation status of our digitalization strategy.
- 5 We have clearly defined the **responsibilities** for implementing the **goals** derived from the strategic consideration on digitalization.
- 6 We have defined a step-by-step **implementation plan** (Digital Roadmap) for achieving the goals.

II Dimension: Information Technology & Process Digitalization

- 7 We exploit the latest digital opportunities to **automate** our **routine processes**.
- 8 Our processes are already **networked** through IT.
- 9 We **know** the most important digital technologies and that they can have an impact on CA.
- 10 We **invest** in digital technologies throughout the CAB (e.g., for digital customer communication, process automation).
- 11 Our internal IT department (or our external service provider) can **ensure** the use of digital technologies relevant to our CAB.
- 12 Our employees are aware of important rules of conduct for **IT-Security** and their compliance is regularly checked (e.g., through audits).

III Dimension: Customers

- 13 Most of the **Interactions** with our customers (e.g., advise, purchase conclusion and customer service) take place via **digital channels**.
- 14 The **provision of services** for customers, as well as customer care are digitally integrated, and personalized.
- 15 We systematically and specifically **analyze** customer needs in order to develop appropriate digital solutions.
- 16 Customer data is **analyzed**, and **relevant actions** are taken accordingly.

IV Dimension: Culture & Expertise

- 17 The **understanding** of the importance of digital transformation is pronounced within our CAB.
- 18 Our CAB is **open** to new technologies, change and transformation.
- 19 We have the right people and **skills** for a successful digital transformation.
- 20 We **accept the risk of failure** in new digital activities.
- 21 We promote the development of digital expertise through targeted **training** of our employees at all levels.

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I Dimension: Strategy	
V Dimension: Organization & Change Management	
22	Digital activities are integrated into the core processes of our CAB .
23	The goals of the digitalization within our CAB are defined and measurable.
24	We have an "early warning" process to identify new, relevant digital technologies or business models for us.
25	The digital transformation is managed on the basis of defined roles, responsibilities and decision-making processes.
26	We are able to react quickly to changes in the technological or market environment.
27	We have enough resources in our day-to-day business to drive digital innovation.
VI Dimension: Innovation	
28	With digitalization, we open a new source of value creation .
29	We drive digital innovations forward systematically and purposefully .
30	We actively involve customers in the development of new digital innovations .
31	We have a clearly defined innovation process for the development, evaluation, and implementation of new ideas by employees and/or customers.
32	We generate competitive advantages through digitalization.
VII Dimension: Cooperation	
33	We work across departments and functions on the topic of digitization.
34	We use exchanges with external experts to build up additional knowledge in the area of digitalization.
35	We collaborate effectively with stakeholders (e.g., customers, suppliers, competitors, scientific institutions) on digital initiatives.
36	In the field of digitalization, we maintain a partner network with external service providers, start-ups, or research institutions.
37	We undertake actions (e.g., workplace concepts) that support employees in collaborating effectively .

References

- J.R. Saura, D. Ribeiro-Soriano, P. Zegarra Saldaña, Exploring the challenges of remote work on Twitter users' sentiments: from digital technology development to a post-pandemic era, *J. Bus. Res.* 142 (2022) 242–254.
- S. Berger, M. Bitzer, B. Häckel, C. Voit, Approaching digital transformation-development of a multi-dimensional maturity model, in: *ECIS 2020 Proceedings*, 2020.
- G. Remane, A. Hanelt, F. Wiesboeck, L. Kolbe, Digital maturity in traditional industries—an exploratory analysis, *ECIS 2017 Proceedings* (2017).
- C. Williams, et al., Digital maturity models for small and medium-sized enterprises: a systematic literature review, in: *ISPIM Conference Proceedings, The International Society for Professional Innovation Management (ISPIM)*, 2019.
- P. Hoàng, H. Pham, Comprehensive Review of Digital Maturity Model and Proposal for a Continuous Digital Transformation Process with Digital Maturity Model Integration, vol. 17, *Sistemas & Gestão*, 2022.
- D. Ifenthaler, M. Eglloffstein, Development and implementation of a maturity model of digital transformation, *TechTrends* 64 (2) (2020) 302–309.
- S. Berghaus, A. Back, Stages in digital business transformation: results of an empirical maturity study, *MCIS 2016 Proceedings* (2016).
- D.R.A. Schallmo, et al., An approach for a digital maturity model for SMEs based on their requirements, in: D.R.A. Schallmo, J. Tidd (Eds.), *Digitalization: Approaches, Case Studies, and Tools for Strategy, Transformation and Implementation*, Springer International Publishing, Cham, 2021, pp. 87–101.
- M. Kohtamäki, et al., The relationship between digitalization and servitization: the role of servitization in capturing the financial potential of digitalization, *Technol. Forecast. Soc. Change* 151 (2020) 119804.
- ISO/IEC, *Conformity Assessment—Vocabulary and General Principles (ISO/IEC 17000:2020)*, 2020. *Trilingual version EN ISO/IEC 17000:2020*.
- P. Castka, et al., Supplier audits during COVID-19: a process perspective on their transformation and implications for the future, *Int. J. Logist. Manag.* 33 (4) (2022) 1294–1314.
- Iaf, *Iaf mandatory document for the use of information and communication technology (ICT) for auditing/assessment purposes, Issue 2, Version 2*, https://iaf.nu/iaf_system/uploads/documents/IAF_MD4_Issue_2_Version_2_03082021.pdf, 2018.
- W. Herding, S. Fischer, *Smart Data: an Exploration into Technology Innovations for Sustainability Standards*, ISEAL Alliance, London, 2015.
- C. Koch, et al., Impact of the COVID-19 pandemic on accredited conformity assessment bodies: insights from a multinational study, *Accred Qual. Assur.* 27 (5) (2022) 275–288.
- M. Mirtsch, et al., Quality assurance in supply chains during the COVID-19 pandemic: empirical evidence on organisational resilience of conformity assessment bodies, *Total Qual. Manag. Bus. Excel.* 34 (5–6) (2023) 615–636.
- J. Becker, B. Niehaves, J. Poeppelbuss, A. Simons, Maturity models in IS research, *ECIS 2010 Proceedings* (2010).
- F. Tuzcek, P. Castka, T. Wakolbinger, A review of management theories in the context of quality, environmental and social responsibility voluntary standards, *J. Clean. Prod.* 176 (2018) 399–416.
- P. Castka, J. Donovan, R. Sousa, Pathways of development of dynamic capabilities for servitization transformation: a longitudinal multi-case study, *Ind. Market. Manag.* 116 (2024) 66–81.
- A. Rossmann, *Digital maturity: conceptualization and measurement model*, Retrieved from, https://www.researchgate.net/profile/Alexander-Rossmann-2/publication/345760193_Digital_Maturity_Conceptualization_and_Measurement_Model/links/5face798299bf18c5b6a0a20/Digital-Maturity-Conceptualization-and-Measurement-Model.pdf, 2018.
- R. Kusa, et al., Entrepreneurial behaviors that shape performance in small family and non-family hotels during times of crisis, *Int. Entrepren. Manag. J.* 18 (4) (2022) 1545–1575.
- R. Teichert, Digital transformation maturity: a systematic review of literature, *Acta Univ. Agric. Silv. Mendelianae Brunensis* 67 (6) (2019) 1673–1687.
- S. Chanas, T. Hess, How digital are we? Maturity models for the assessment of a company's status in the digital transformation, *Management Report/Institut für Wirtschaftsinformatik und Neue Medien* (2) (2016) 1–14.
- P. Weritz, J. Braojos, J. Matute, Exploring the antecedents of digital transformation: dynamic capabilities and digital culture aspects to achieve digital maturity, *AMCIS 2020 Proceedings* (2020).
- G. Lahrmann, F. Marx, T. Mettler, R. Winter, F. Wortmann, Inductive design of maturity models: applying the Rasch Algorithm for design science research, in: H. Jain, A.P. Sinha, P. Vitharana (Eds.), *Service-Oriented Perspectives in Design Science Research. DESRIST 2011. Lecture Notes in Computer Science*, vol. 6629, Springer, Berlin, Heidelberg, 2011.
- G.C. Kane, D. Palmer, A. Nguyen-Phillips, D. Kiron, N. Buckley, Achieving digital maturity, *MIT Sloan Management Review and Deloitte University Press* 59 (1) (2017).
- D. Rader, Digital maturity – the new competitive goal, *Strat. Leader.* 47 (5) (2019) 28–35.
- T. De Bruin, M. Rosemann, R. Freeze, U. Kaulkarni, Understanding the main phases of developing a maturity assessment model, in: Paper Presented at the Australasian Conference on Information Systems (ACIS), 2005.
- D. Friedel, A. Back, Determination of enterprise 2.0 development levels with a maturity model, in: *Proceedings of the IADIS International Conferences*, 2012.
- N. Frick, T.F. Küttner, P. Schubert, Assessment methodology for a maturity model for interorganizational systems—the search for an assessment procedure, in: Paper Presented at the 2013 46th Hawaii International Conference on System Sciences, 2013.
- J. Poeppelbuss, et al., Maturity models in information systems research: literature search and analysis, *Commun. Assoc. Inf. Syst.* 29 (1) (2011) 27.
- E. Henriette, M. Feki, I. Boughzala, Digital transformation challenges, *MCIS 2016 Proceedings* (2016).
- C. van Tonder, C. Schachtebeck, C. Nieuwenhuizen, B. Bossink, A framework for digital transformation and business model innovation, *Management* 25 (2) (2020) 111–132.
- A. Mayo, C. Parokkil, *BSI Whitepaper: the role of standards in supporting the transition to a digital economy and facilitating digital trade*, Retrieved from, <https://www.bsigroup.com/globalassets/localfiles/en-th/our-service/international-projects/bsi-transition-to-a-digital-economy-whitepaper-th.pdf>, 2021.
- M. Mirtsch, The role of conformity assessment in the digital transformation: focusing on cybersecurity, in: *EURAS Proceedings 2018- Standards for a Smarter Future*, Verlagshaus Mainz GmbH: Aachen, 2018.
- M. Arnold, R.K. Bellamy, M. Hind, S. Houde, S. Mehta, A. Mojsilović, D. Piorowski, *FactSheets: increasing trust in AI services through supplier's declarations of conformity*, *IBM J. Res. Dev.* 63 (4/5) (2019) 6:1–6:13.
- P. Castka, C. Searcy, S. Fischer, Technology-enhanced auditing in voluntary sustainability standards: the Impact of COVID-19, *Sustainability* 12 (11) (2020) 4740.
- Boston Consulting Group, *It's time for TICC companies to catch up on digital*, Retrieved from, <https://web-assets.bcg.com/cf/a2/144214eb41e8a3e9dd5adec8a6b0/bcg-it-is-time-for-ticc-companies-to-catch-up-on-digital.pdf>, 2021.
- S. Berghaus, A. Back, Stages in digital business transformation: results of an empirical maturity study, *MCIS 2016 Proceedings* (2016).
- J. Webster, R.T. Watson, Analyzing the past to prepare for the future: Writing a literature review, *MIS Q.* 26 (2) (2002) xiii–xxiii.

- [40] J. Becker, B. Niehaves, J. Poeppelbuss, A. Simons, Maturity models in IS research, *ECIS 2010 Proceedings* (2010).
- [41] S.G. Winter, Understanding dynamic capabilities, *Strat. Manag. J.* 24 (10) (2003) 991–995.
- [42] K.M. Eisenhardt, J.A. Martin, Dynamic capabilities: what are they? *Strat. Manag. J.* 21 (10–11) (2000) 1105–1121.
- [43] G. Vial, Understanding digital transformation: a review and a research agenda, *J. Strat. Inf. Syst.* 28 (2) (2019) 118–144.
- [44] G.C. Kane, et al., Strategy, not technology, drives digital transformation, *MIT Sloan Management Review and Deloitte University Press* 14 (1–25) (2015).
- [45] J. Karimi, Z. Walter, The role of dynamic capabilities in responding to digital disruption: a factor-based study of the newspaper industry, *J. Manag. Inf. Syst.* 32 (1) (2015) 39–81.
- [46] T. Papadopoulos, K.N. Baltas, M.E. Balta, The use of digital technologies by small and medium enterprises during COVID-19: implications for theory and practice, *Int. J. Inf. Manag.* 55 (2020) 102192.
- [47] F.T. Rothaermel, A.M. Hess, Building dynamic capabilities: innovation driven by individual-, firm-, and network-level effects, *Organ. Sci.* 18 (6) (2007) 898–921.
- [48] M.A. Sánchez, A framework to assess organizational readiness for the digital transformation, *Dimensión Empresarial* 15 (2) (2017) 27–40.
- [49] J.Y. Thong, An integrated model of information systems adoption in small businesses, *J. Manag. Inf. Syst.* 15 (4) (1999) 187–214.
- [50] D. Collins, Pretesting survey instruments: an overview of cognitive methods, *Qual. Life Res.* 12 (3) (2003) 229–238.
- [51] A. Bharadwaj, et al., Digital business strategy: toward a next generation of insights, *MIS Q.* (2013) 471–482.
- [52] StataCorp, *Stata Statistical Software: Release 16*, StataCorp LLC, College Station, TX, 2019.
- [53] J. Kampen, M. Swyngedouw, The ordinal controversy revisited, *Qual. Quantity* 34 (1) (2000) 87–102.
- [54] Wiley, *Digital Skills Gap Index 2021, 2021*. Retrieved from, <https://dsgi.wiley.com/>.
- [55] H. Guo, et al., The digitalization and public crisis responses of small and medium enterprises: implications from a COVID-19 survey, *Front. Bus. Res. China* 14 (1) (2020) 1–25.
- [56] C. Koch, et al., Impact of the COVID-19 pandemic on conformity assessment: insights from a multinational study, in: K. Jakobs (Ed.), 25th EURAS Annual Standardisation Conference - Standardisation and Innovation SIIT 2021: the Past, Present and Future of ICT Standardisation, RWTH Aachen, Aachen, 2021, pp. 379–398.
- [57] P. Soto-Acosta, COVID-19 pandemic: shifting digital transformation to a high-speed gear, *Inf. Syst. Manag.* 37 (4) (2020) 260–266.
- [58] J. Brodny, M. Tutak, Assessing the level of digital maturity of enterprises in the Central and Eastern European countries using the MCDM and Shannon's entropy methods, *PLoS One* 16 (7) (2021) e0253965.
- [59] A. Małkowska, M. Urbaniec, M. Kosala, The impact of digital transformation on European countries: insights from a comparative analysis, *Equilibrium. Quarterly Journal of Economics and Economic Policy* 16 (2) (2021) 325–355.
- [60] R. van Kessel, et al., Is Europe prepared to go digital? Making the case for developing digital capacity: an exploratory analysis of Eurostat survey data, *PLOS Digital Health* 1 (2) (2022) e0000013.
- [61] M.C. Morandini, et al., *Facing The Digital Transformation: Are Digital Skills Enough?* European Economy - Economic Briefs 054, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission, 2020.
- [62] M. Astuti, et al., The maturity levels of the digital technology competence in vocational education, *Int. J. Eval. Res. Educ.* 11 (2) (2022) 596–603.
- [63] J. Bughin, T. Kretschmer, N.v. Zeebroeck, Digital technology adoption drives strategic renewal for successful digital transformation, *IEEE Eng. Manag. Rev.* 49 (3) (2021) 103–108.
- [64] E. Enkel, O. Gassmann, H. Chesbrough, Open R&D and open innovation: exploring the phenomenon, *R&D Management* 39 (2009) 311–316.
- [65] A. Lazić, M. Jović, Strategic digital transformation of organisations, in: 5th IPMA SENET Project Management Conference (SENET 2019) Proceedings, 2019.
- [66] Z. Korachi, B. Bounabat, Towards a maturity model for digital strategy assessment, in: M. Ezziyyani (Ed.), *Advanced Intelligent Systems for Sustainable Development, AI2SD'2019, 2020*, p. 1105.
- [67] M. Shahiduzzaman, M. Kowalkiewicz, R. Barrett, M. McNaughton, *Digital Business: towards a Value Centric Maturity Model, Part B*, PWC Chair in Digital Economy/Queensland University of Technology, Queensland, 2017. Retrieved from, <https://research.qut.edu.au/cde/wp-content/uploads/sites/279/2021/03/Digital-Business-Part-B.pdf>.
- [68] A. Cavallo, et al., The evolving nature of open innovation governance: a study of a digital platform development in collaboration with a big science centre, *Technovation* 116 (2022) 102370.
- [69] J.R. Saura, D. Palacios-Marqués, D. Ribeiro-Soriano, Exploring the boundaries of open innovation: evidence from social media mining, *Technovation* 119 (2023) 102447.
- [70] N. Islam, P. Buxmann, D. Ding, Fostering digital innovation through inter-organizational collaboration between incumbent firms and start-ups, *ECIS* (2017). Proceedings.
- [71] J.R. Saura, et al., Consumer behavior in the digital age, *Journal of Spatial and Organizational Dynamics* 8 (3) (2020) 190–196.
- [72] S.R. Colwell, A.W. Joshi, Corporate ecological responsiveness: antecedent effects of institutional pressure and top management commitment and their impact on organizational performance, *Bus. Strat. Environ.* 22 (2) (2013) 73–91.
- [73] B. Latif, et al., Coercive, normative and mimetic pressures as drivers of environmental management accounting adoption, *Sustainability* 12 (11) (2020) 4506.
- [74] D. Horváth, R.Z. Szabó, Driving forces and barriers of Industry 4.0: do multinational and small and medium-sized companies have equal opportunities? *Technol. Forecast. Soc. Change* 146 (2019) 119–132.
- [75] D. Kiel, et al., Sustainable industrial value creation: benefits and challenges of industry 4.0, *Int. J. Innovat. Manag.* 21 (8) (2017) 1740015.
- [76] J.B. Barney, Resource-based theories of competitive advantage: a ten-year retrospective on the resource-based view, *J. Manag.* 27 (6) (2001) 643–650.
- [77] O.A. Acar, M. Tarakci, D. Van Knippenberg, Creativity and innovation under constraints: a cross-disciplinary integrative review, *J. Manag.* 45 (1) (2019) 96–121.
- [78] M. Mirtsch, J. Kinne, K. Blind, Exploring the adoption of the international information security management system standard ISO/IEC 27001: a web mining-based analysis, *IEEE Trans. Eng. Manag.* 68 (1) (2021) 87–100.