

Article

Perceived Sustainable Digital Transformation Adoption in Retail: A Capability-Mediated Technology–Organization–Environment Perspective

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Abstract

The increasing emphasis on sustainability and digitalization is reshaping retail environments, requiring organizations to respond simultaneously to technological change and sustainability-oriented pressures. However, the relationships between these external demands and the perceived sustainable digital transformation adoption, as well as the role of internal organizational conditions in these relationships, remain insufficiently understood. This study develops a conceptual model examining the direct and indirect associations among external sustainability pressures, digital capability, organizational readiness, and perceived adoption in Romanian retail organizations. Digital capability and organizational readiness are conceptualized as distinct internal enabling conditions within an extended Technology–Organization–Environment framework, while perceived sustainable digital transformation adoption is defined as the reported outcome. The model is evaluated using partial least squares structural equation modeling (PLS-SEM) and cross-sectional survey data from 363 retail professionals representing 363 distinct Romanian retail organizations. The results indicate that the direct associations of digital capability and organizational readiness with perceived adoption are larger than the direct association of external sustainability pressures with perceived adoption. External sustainability pressures show a statistically significant but small direct association, together with significant indirect associations through digital capability and organizational readiness. The findings are consistent with a capability-mediated interpretation; however, the cross-sectional design and self-reported data do not establish causal or temporal relationships.

Keywords: perceived sustainable digital transformation adoption; retail; TOE; digital capability; organizational readiness; sustainability pressures

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1. Introduction

Sustainable Digital Transformation (SDT) is increasingly regarded as a strategically important process for retail organizations, whose operating environments have become both more data-intensive and more demanding in terms of sustainability [1–3]. In these settings, digitalization is rarely pursued for efficiency alone; it is also associated with ef-

forts to redesign customer interactions and respond to increasingly prominent sustainability expectations [4–6]. At the same time, the adoption of technologies such as artificial intelligence, cloud-based systems, and advanced analytics has changed core processes, including supply-chain coordination and decision-making routines [7,8].

Adoption across the sector remains uneven [8,9]. Some organizations advance more rapidly, whereas others experience slower or more fragmented transformation processes [2,10,11]. This divergence may not be explained by technological investment alone. It may also reflect how organizations align internal processes with digital investments, integrate sustainability priorities into existing practices, and respond to regulatory and market pressures [11]. These observations point to the importance of internal organizational conditions in explaining differences in adoption.

The Technology–Organization–Environment (TOE) framework is widely used to explain technology adoption, as it integrates technological capabilities, organizational conditions, and environmental pressures within a unified perspective [12,13]. TOE has also been applied to digital-transformation and online-retailing contexts [9,11].

In TOE-based adoption research, environmental factors such as competition, regulatory requirements, and sustainability-related expectations are frequently modeled as direct antecedents of adoption alongside technological and organizational conditions [12,14–16]. However, findings obtained in settings characterized by strong competitive pressures or substantial institutional variation may partly reflect those contextual conditions, making it important to distinguish general TOE relationships from context-specific patterns.

Retailers are experiencing increasing sustainability-related pressures, including environmental regulation, ESG expectations, and changing consumer preferences for more sustainable products and services [17–19]. Although organizations operating within the same national market may share parts of the regulatory and institutional context, the extent to which these pressures are perceived similarly across firms remains an empirical question.

Retail organizations operating within the same national and sectoral context may be exposed to broadly shared regulatory and market conditions. In the present study, environmental homogeneity was not directly measured and is therefore treated as a contextual boundary condition rather than an empirical finding. The analysis consequently examines whether internal organizational conditions show stronger associations with perceived adoption than external sustainability pressures, without assuming that the external environment is uniform.

Against this background, a predominantly direct-effects specification may provide an incomplete account in single-country and sector-specific settings where organizations operate within a shared institutional framework [12,14,17]. The role of sustainability-related pressures within TOE therefore warrants examination through both direct and indirect associations, without presuming that such pressures are homogeneous.

This issue is particularly relevant in retail contexts, where digital transformation is increasingly linked to broader sustainability-oriented business model changes [12,17]. As a result, the relative magnitude of the direct and indirect associations among external sustainability pressures, internal organizational conditions, and perceived adoption remains insufficiently understood.

Previous TOE research has already examined indirect, moderating, and context-dependent configurations, and capability-based perspectives have similarly emphasized that organizational responses to external change depend on the mobilization and reconfiguration of internal resources [12,14]. Dynamic-capabilities theory therefore provides a complementary perspective for interpreting digital capability and organizational readiness as internal enabling conditions, although these constructs are not treated as direct

measures of dynamic capabilities in the present study. In light of these circumstances, the contribution of the study is incremental: it specifies and tests, in Romanian retail organizations, direct, parallel indirect, and sequential indirect associations linking external sustainability pressures, digital capability, organizational readiness, and perceived adoption.

The retail sector therefore provides a relevant empirical setting for examining whether external sustainability pressures are associated with perceived sustainable digital transformation adoption directly or through digital capability and organizational readiness [20,21]. Examining these relationships within a shared national and sectoral context may provide a more context-sensitive account of sustainable digital transformation without assuming causal or temporal mechanisms.

This study examines the associations among external sustainability pressures, digital capability, organizational readiness, and perceived sustainable digital transformation adoption in Romanian retail organizations. It assesses both direct and specific indirect associations using Partial Least Squares Structural Equation Modeling (PLS-SEM) applied to cross-sectional survey data from retail professionals [22].

Despite growing interest in sustainable digital transformation, evidence remains limited regarding these relationships in Romanian retail organizations. The study treats the shared national and sectoral setting as a contextual boundary condition rather than as evidence of environmental homogeneity. The following research questions guide the analysis:

RQ1: How are digital capability, organizational readiness, and external sustainability pressures associated with perceived sustainable digital transformation adoption in retail organizations?

RQ2: To what extent are indirect associations between external sustainability pressures and perceived adoption observed through digital capability and organizational readiness?

The results suggest that external sustainability pressures have a smaller direct association with perceived sustainable digital transformation adoption than the corresponding direct associations of digital capability and organizational readiness. These two internal conditions therefore have greater explanatory relevance within the specified model. External sustainability pressures remain relevant through a small direct association with perceived adoption and significant indirect associations involving organizational readiness and digital capability. Collectively, this pattern is consistent with a capability-mediated interpretation of perceived adoption in sustainability-oriented retail environments.

This study provides an incremental extension of TOE-based research by examining a capability-mediated configuration in Romanian retail rather than by claiming that indirect environmental relationships are theoretically new. Its contribution lies in specifying a model in which digital capability and organizational readiness remain empirically distinct internal conditions and in comparing the direct association of external sustainability pressures with perceived adoption against parallel and sequential indirect associations through these constructs. The resulting account is context-specific and concerns respondents' perceptions of adoption; it should not be interpreted as evidence of objectively verified environmental performance or causal capability development.

The remainder of the article is organized as follows. Section 2 presents the literature review, Section 3 develops the research model and hypotheses, Section 4 describes the methodology, Section 5 reports the empirical results, Section 6 discusses the findings, and Section 7 presents the conclusions, managerial implications, limitations, and directions for future research.

2. Literature Review

2.1. Theoretical Perspectives on Sustainable Digital Transformation

Digital transformation is often described in the literature as a form of organizational change driven by digital technologies, although the way this concept is framed varies considerably from one study to another [3,8,16]. In many of the earlier discussions, the emphasis was primarily operational, focusing on how digital tools were introduced into existing processes, mostly with the aim of improving efficiency at the operational level [23–25].

More recent research suggests that transformation also depends on how organizations coordinate resources, support strategic initiatives, and adapt to changing business requirements [8,12,26]. From this perspective, technology is viewed less as a standalone objective and more as part of a broader process of organizational adaptation.

At the organizational level, digital transformation is commonly conceptualized as an ongoing process rather than as a single adoption decision. This process-oriented perspective emphasizes the continuing development, coordination, and reconfiguration of technological and organizational resources in response to changing business and institutional conditions [3,8,9].

Dynamic-capabilities theory complements this process-oriented perspective by emphasizing an organization's capacity to identify environmental changes, mobilize resources, and reconfigure routines and competencies in response to emerging demands [14]. In the present study, digital capability and organizational readiness are interpreted as distinct internal enabling conditions consistent with a capability-based perspective; they are not operationalized as direct measures of dynamic capabilities. Digital capability refers to the organization's technological capacity, whereas organizational readiness refers to its managerial, strategic, human, and resource-related preparedness to support transformation.

2.2. Sustainable Digital Transformation in the Retail Sector

Sustainable digital transformation in retail is increasingly discussed as a strategic organizational process involving changes in operations, value creation, business models, and relationships with customers and other stakeholders [17,20]. At the customer-facing level, digital transformation also includes social-media communication, which has been examined in relation to online customer relationships and brand management [27]. Earlier approaches tended to frame digitalization in more limited terms, primarily as the integration of new technologies into existing processes [21,25]. More recent perspectives place greater emphasis on broader organizational implications, including resource coordination, managerial involvement, and the alignment of digital initiatives with longer-term strategic and sustainability-oriented directions [10,28–30].

These dynamics are particularly relevant in retail, where organizations face pressures to improve supply-chain efficiency, reduce environmental impacts, and respond to consumer demand for more sustainable products and practices [7,25,26]. These pressures connect digital transformation with broader sustainability-oriented operational and strategic change.

Retail organizations do not progress at the same pace. Variation in digital maturity, system integration, and the capacity to implement sustainability-oriented initiatives is associated with different levels of adoption and implementation [31–34]. Regulatory requirements and ESG-related expectations add to existing competitive pressures [35–37]. Together, these conditions provide a rationale for examining the associations among external sustainability pressures, digital capability, organizational readiness, and perceived sustainable digital transformation adoption in retail.

2.3. Conceptualizing Sustainable Digital Transformation Through the TOE Framework

The Technology–Organization–Environment (TOE) framework was developed by Tornatzky and Fleischer [38] and is often applied in attempts to understand how organizations adopt new technologies. This is largely because the framework does not restrict the explanation to one type of factor. Instead, it brings together technological aspects, internal organizational conditions, and elements from the external environment, allowing adoption processes to be viewed in a more connected way. In research on digital transformation, this perspective has been applied across different industries, from manufacturing to services and e-commerce, mainly to explain why organizations differ in the way and speed with which they implement digital solutions [17,35,39,40].

In the present study, the technological dimension is represented by digital capability, including digital infrastructure, system integration and interoperability, analytics use, employee digital competence, and continued technological investment [32,41,42]. The organizational dimension is represented by organizational readiness, including top-management support, strategic direction, employee adaptability, and the availability of financial, human, and technical resources [43,44]. The two constructs are conceptually related but distinct: digital capability concerns the organization's technological capacity, whereas organizational readiness concerns its preparedness to organize, resource, and support transformation. Perceived sustainable digital transformation adoption is modeled separately as the reported adoption outcome rather than as an internal capability or an objectively verified measure of environmental performance.

The environmental dimension refers to the context in which organizations operate, including competition, regulatory frameworks, industry standards, and stakeholder expectations. In sustainability-oriented settings, these influences increasingly include ESG requirements and policy initiatives related to the green transition [18,19,36]. Existing research often models environmental pressures as direct antecedents of technology adoption [9,17,30,45]. The present study extends this specification by also examining whether their associations with perceived adoption are observed indirectly through digital capability and organizational readiness.

TOE research has examined digital transformation in settings characterized by intense competition and substantial variation in regulatory conditions [12,14,46]. In these settings, environmental factors may have a direct role in adoption decisions alongside technological and organizational factors [21,47]. The magnitude and interpretation of these associations may vary across national, institutional, and sectoral contexts. Findings obtained in highly competitive or institutionally diverse settings should not be assumed to apply without qualification to Romanian retail organizations.

Organizations operating within the same national and sectoral setting may share elements of the regulatory and institutional environment while perceiving and responding to those conditions differently. Because environmental homogeneity was not directly measured, the shared Romanian retail context is treated as a contextual boundary condition rather than as an empirical finding. The empirical question is how the direct association between external sustainability pressures and perceived adoption compares with the associations involving digital capability and organizational readiness, and whether indirect associations are observed through these internal conditions.

Prior TOE research has already considered indirect, moderating, and context-dependent configurations [12,14]. The remaining gap is therefore not whether environmental factors can ever be related indirectly to adoption, but how sustainability-related external pressures are associated with digital capability, organizational readiness, and perceived adoption in Romanian retail. The present study addresses this narrower gap by estimating a direct association between ESP and SDTA, two parallel specific indirect as-

sociations through ORF and DCF, and a sequential specific indirect association through DCF and ORF.

Accordingly, the study applies a capability-mediated TOE specification in which perceived adoption is examined in relation to digital capability, organizational readiness, and external sustainability pressures. The model includes direct paths from DCF, ORF, and ESP to SDTA, paths from ESP to DCF and ORF, and a path from DCF to ORF. These paths permit the estimation of direct, parallel indirect, and sequential indirect associations. Because the study is cross-sectional, the direction of the paths reflects the theoretically specified model and does not establish temporal ordering.

The framework is adapted to the retail context, and the resulting model is estimated using Partial Least Squares Structural Equation Modeling (PLS-SEM). This method permits the simultaneous evaluation of multiple latent constructs and direct, parallel indirect, and sequential indirect associations [22].

3. Research Model and Hypotheses

The proposed model specifies both direct and indirect associations among the technological, organizational, and environmental dimensions of the TOE framework. Building on the preceding discussion, it organizes the relationships among digital capability, organizational readiness, external sustainability pressures, and perceived sustainable digital transformation adoption. The framework is applied to sustainability-oriented retail by examining how these constructs are statistically related rather than by treating perceived adoption as the outcome of isolated factors.

The model includes internal organizational conditions and external environmental pressures. In retail, sustainability requirements, regulatory expectations, and changing consumer preferences may be experienced simultaneously. The specified paths therefore distinguish direct associations with perceived adoption from indirect associations through digital capability and organizational readiness (Figure 1). Because the study is cross-sectional, the model does not establish that some relationships occur more immediately or develop more gradually than others.

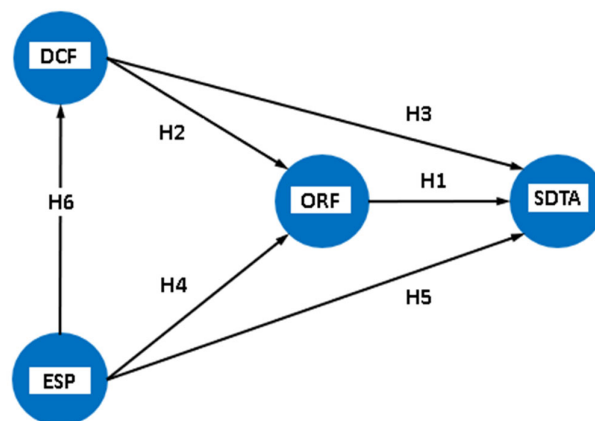


Figure 1. Conceptual model of perceived sustainable digital transformation adoption based on the TOE framework.

The conceptual model builds on existing technology-adoption research but adapts it to the organizational level. Rather than relying on individual technology-acceptance beliefs, it focuses on respondents' assessments of organization-level digital capability, organizational readiness, external sustainability pressures, and perceived adoption. Exter-

nal sustainability pressures are included as a construct with both direct and indirect associations in the specified model.

Figure 1 summarizes the specified relationships among the constructs. Perceived sustainable digital transformation adoption is the outcome of interest, while digital capability, organizational readiness, and external sustainability pressures represent the technological, organizational, and environmental dimensions of the model. The model includes both direct associations and indirect associations through internal conditions, consistent with the theoretical arguments developed from prior TOE-based research [14,46]. These paths represent theoretically specified relationships and should not be interpreted as observed temporal sequences.

3.1. Determinants of Sustainable Digital Transformation in Retail Organizations

The preceding arguments indicate the need to examine the relationships among digital capability, organizational readiness, external sustainability pressures, and perceived sustainable digital transformation adoption. Within the TOE perspective, the present study focuses on both the direct and indirect associations specified among these constructs.

From a technological perspective, what matters most is not simply the presence of digital tools, but how well organizations are able to use them. In retail settings, this usually goes beyond basic infrastructure and includes aspects such as data integration, system compatibility, and the use of advanced analytics in decision-making. These capabilities can support more efficient use of resources and help organizations address sustainability-related challenges. In many cases, their contribution becomes visible only when they are consistently embedded in everyday operations.

Looking at the organizational side, the picture becomes slightly more nuanced. Transformation depends to a large extent on how internal processes are aligned and how different parts of the organization work together. Elements such as leadership support, availability of resources, and openness to change play an important role, but not in isolation. What often makes a difference is how these elements are combined and whether they support a coherent direction, especially when sustainability objectives are involved. In retail environments, where operational demands remain high, maintaining this balance is not always straightforward.

The external environment adds another layer of complexity. Retail organizations are increasingly exposed to sustainability-related pressures, including regulatory requirements, ESG expectations, and shifts in consumer behavior [48–50]. The extent to which these pressures are perceived similarly across organizations was not measured in the present study. Their direct association with perceived adoption and their associations with digital capability and organizational readiness are therefore treated as empirical questions rather than as assumed mechanisms.

TOE-based research frequently models environmental factors as direct antecedents of adoption [14,46,51]. The magnitude and interpretation of these relationships may vary across national, institutional, and sectoral contexts. The present study therefore examines both direct and indirect associations without assuming that the Romanian retail environment is standardized or homogeneous.

Taking these aspects into account, the study adopts a capability-oriented interpretation of sustainable digital transformation. It examines whether external sustainability pressures are associated directly with perceived adoption and indirectly through digital capability and organizational readiness. These associations are evaluated within the specified cross-sectional model and are not interpreted as evidence of gradual or temporally ordered organizational adjustments.

3.2. Organizational Readiness and Perceived Sustainable Digital Transformation Adoption

Within the TOE framework, the organizational dimension concerns the extent to which firms are prepared to initiate and support transformation processes. In sustainable digital transformation, this preparedness involves the alignment of internal structures, managerial practices, and available resources in support of organizational outcomes [52]. The construct therefore concerns not only the presence of these elements but also their coordinated deployment.

In retail organizations, transformation rarely unfolds in a controlled or linear way. Activities are closely interconnected, and interactions with customers and supply chain partners are constant. Under these conditions, simply having access to technology is not enough. Outcomes depend to a large extent on how well internal processes are aligned, how effectively different functions are coordinated, and whether the organization is able to support change across multiple levels at the same time [44,53].

Managerial involvement is associated with the prioritization of initiatives, resource allocation, and the internal interpretation of transformation. When leadership engagement is supported by a clear strategic direction, digital initiatives are more likely to be integrated into broader organizational objectives, including sustainability-related ones [54].

Differences in organizational readiness may help explain why organizations operating within the same national and sectoral context report different levels of perceived adoption [53,55,56]. Relevant differences may concern the availability of skills, the flexibility of organizational routines, and the capacity to manage change. Because environmental homogeneity was not measured, these differences should not be interpreted as evidence that the organizations faced identical or consistently similar sustainability pressures.

Organizational readiness is therefore specified as having a direct association with perceived sustainable digital transformation adoption. It is also positioned as an internal condition associated with digital capability, consistent with the DCF → ORF path included in the structural model.

Hypothesis 1 (H1). *Organizational readiness is positively associated with perceived sustainable digital transformation adoption in retail organizations.*

3.3. Digital Capability and Perceived Sustainable Digital Transformation Adoption

Technological innovation is often discussed as a key driver of digital transformation, but in practice its role is a bit more nuanced than it might initially appear. It does provide organizations with the tools needed to rethink processes, improve how value is delivered, and adjust business models to a more digital setting [21,55,57]. Within the TOE perspective, the technological dimension is usually associated with how far organizations are able to develop and actually use these technologies in support of transformation efforts, although the effective use of these technologies varies across organizations.

In retail contexts, technological readiness tends to go well beyond simply having the necessary infrastructure in place. What matters most is how effectively organizations are able to use these technologies. Given the complexity of retail operations—especially the coordination of supply chains and the constant interaction with customers—these capabilities become increasingly important [58,59]. They allow organizations to respond more quickly and, in some cases, more accurately, although this often depends on how consistently such tools are integrated into daily practices.

Existing research indicates that technologies such as data analytics, artificial intelligence, and integrated digital platforms can support efficiency and customer-related processes [15,60,61]. In retail, better integration of IT systems often makes coordination across logistics, sales, and administrative functions easier. Digital capability may also be associ-

ated with organizational readiness because integrated infrastructure, analytics, employee competence, and established digital routines can support coordinated processes and strategic decision-making [42,57,58].

Based on these arguments, the role of digital capabilities in supporting organizational transformation becomes difficult to ignore, even if the relationship is not always entirely straightforward. Organizations that have more developed digital infrastructure, stronger analytical capabilities, and systems that work well together are generally in a better position to move forward with transformation initiatives [49,58]. In many cases, they are also more able to make use of the opportunities associated with digitalization, including those linked to sustainability, although the extent to which this happens can vary.

Digital capability is therefore specified as having a direct association with perceived adoption and an association with organizational readiness. These relationships correspond to the DCF $\rightarrow$ SDTA and DCF $\rightarrow$ ORF paths included in the structural model. The specified path direction reflects the theoretical model and does not establish that digital capability necessarily develops before organizational readiness. Based on the theoretical arguments presented, the following hypotheses are formulated:

Hypothesis 2 (H2). *Digital capability is positively associated with organizational readiness.*

Hypothesis 3 (H3). *Digital capability is positively associated with perceived sustainable digital transformation adoption in retail organizations.*

3.4. External Sustainability Pressures and Perceived Sustainable Digital Transformation Adoption

In discussions of technology adoption, the external environment is typically used to describe the broader institutional and market context in which organizations operate, although in practice these influences are not always clearly separable [9,15]. In sustainability-oriented retail settings, this context is increasingly shaped by regulatory frameworks, environmental standards, stakeholder expectations, and gradual shifts in consumer preferences toward more responsible forms of consumption.

Retail organizations are exposed to sustainability-related pressures arising from ESG requirements, policy initiatives, and public concern regarding environmental impacts [35,36]. These pressures may be associated with organizational priorities and with the reported integration of sustainability considerations into digital-transformation initiatives. The present study does not assume that organizations within the same regulatory and market context perceive or respond to these pressures in similar ways.

Shared regulatory requirements and market expectations may establish elements of a common institutional context, while organizations may still perceive and respond to them differently. Because the degree of environmental homogeneity was not measured, the present study does not assume that organizations were exposed to broadly comparable pressures or that differences in perceived adoption can be attributed to limited external variation.

In the specified model, external sustainability pressures are examined in relation to digital capability, organizational readiness, and perceived adoption [30,49]. The indirect paths test whether the association between external sustainability pressures and perceived adoption is also observed through the two internal conditions. These paths represent statistical associations and do not establish that external pressures temporally precede or cause the development of digital capability or organizational readiness.

Capability-based and institutional perspectives provide a theoretical rationale for examining digital capability and organizational readiness as distinct internal conditions associated with external sustainability pressures and perceived adoption [8,14,20,62]. The

resulting model is consistent with a capability-mediated interpretation, but the cross-sectional estimates do not establish a capability-building process or the temporal translation of external pressures into organizational outcomes.

Under these circumstances, external sustainability pressures are examined in terms of their direct association with perceived sustainable digital transformation adoption and their associations with digital capability and organizational readiness. These specified relationships also permit the estimation of indirect associations with perceived adoption through the internal constructs. Based on this reasoning, the following hypotheses are proposed:

Hypothesis 4 (H4). *External sustainability pressures are positively associated with organizational readiness in retail organizations.*

Hypothesis 5 (H5). *External sustainability pressures are positively associated with perceived sustainable digital transformation adoption in retail organizations.*

Hypothesis 6 (H6). *External sustainability pressures are positively associated with digital capability in retail organizations.*

4. Research Methodology

This study employed a quantitative, cross-sectional survey design to examine the associations among digital capability, organizational readiness, external sustainability pressures, and perceived sustainable digital transformation adoption in retail organizations. Data were collected through a self-report questionnaire assessing respondents' perceptions of these organizational conditions. The design enabled the statistical examination of the proposed direct and indirect associations but did not permit causal or temporal inferences.

The empirical analysis was based on data collected from professionals employed in retail organizations in Romania. Respondents occupied senior-management, middle-management, or specialist positions and participated in digital transformation activities as decision-makers, technical specialists, or operational users. Participants were selected based on their involvement in digital transformation activities and their familiarity with relevant organizational practices. A purposive non-probability sampling approach was therefore used to reach informed respondents within the retail sector.

The final sample comprised 363 professionals, each employed in and reporting on a different retail organization; thus, the responses represented 363 distinct organizations. The unit of observation was the individual respondent, and the measures were organization-referent assessments provided by a single knowledgeable informant from each organization. Accordingly, the analysis concerns perceived organizational conditions rather than independently verified organization-level attributes. Because only one respondent was included per organization, there was no within-organization clustering of respondents to model; however, within-organization agreement could not be assessed. Environmental homogeneity was not directly measured and is therefore treated as a contextual boundary condition rather than an empirical finding.

The questionnaire was developed with reference to prior research on digital transformation, sustainability, and technology adoption and was aligned with the TOE framework. The measurement items were developed by the authors based on construct domains identified in the cited literature and were contextualized for sustainability-oriented digital transformation in retail organizations. The complete item wording, together with the literature basis, operational focus, and nature of item development, is presented in Appendix A, Table A1.

Digital capability was measured using five items addressing digital infrastructure, system integration and interoperability, data analytics, employee digital competence, and continued investment in digital technologies. Organizational readiness was measured using four items addressing top-management support, strategic direction, employee adaptability, and the availability of financial, human, and technical resources. External sustainability pressures were measured using four items addressing regulatory requirements, customer expectations, industry standards and competitive influences, and environmental and ESG-related pressures. Perceived sustainable digital transformation adoption was measured using six items addressing the evaluation, strategic integration, use, implementation, and continued adoption of digital solutions intended to support sustainability-related objectives. Accordingly, the outcome construct captures respondents' perceptions of sustainability-oriented digital adoption and does not represent independently verified environmental performance.

The questionnaire included 19 items measuring digital capability, organizational readiness, external sustainability pressures, and perceived sustainable digital transformation adoption. Additional information was collected on gender, age, education, professional field, respondent position, role in digital transformation, and the retail segment represented by the respondent's organization. All construct items were measured on a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

Before the main data collection, the questionnaire was pre-tested with 10 participants experienced in digital transformation and retail operations. Based on their feedback, minor wording revisions were made to improve item clarity and consistency. A pilot study involving 40 respondents was then conducted to assess item comprehension, preliminary reliability, and instrument usability. The pilot results supported proceeding with the full-scale data collection, and the pilot responses were not included in the final analytical sample. No further substantive changes to the questionnaire were made after the pilot study.

The survey link was distributed online to professionals employed in Romanian retail organizations through direct professional contacts and LinkedIn. Participation was voluntary and anonymous. Before beginning the questionnaire, respondents were informed about the purpose of the study, the intended academic use of the data, the voluntary nature of participation, the anonymous processing of responses, and the applicable data-protection requirements. Respondents provided informed consent before beginning the survey and could discontinue participation at any time before submission by closing the questionnaire. To reduce the potential for common method variance, the items were formulated in clear language, and the constructs were presented in conceptually separated sections. No directly identifying personal data were collected.

Data were collected through an online self-administered survey between January and March 2026. The survey invitation was sent to 470 eligible retail professionals, of whom 412 submitted questionnaires, corresponding to a response rate of 87.66%. The received questionnaires were subsequently screened for completeness and response consistency. Forty-nine questionnaires were excluded because of missing data, straight-lining patterns, or unusually short completion times. The final analytical sample comprised 363 valid responses from 363 distinct retail organizations, yielding a usable response rate of 77.23% relative to the individuals invited.

Table 1 presents the demographic and professional characteristics of the 363 respondents and the retail segments represented in the sample. The respondents worked in retail operations, business and marketing, digital services and e-commerce, information technology, and other functional areas. They occupied senior-management, middle-management, or specialist positions and participated in digital transformation as decision-makers, technical specialists, or operational users. The represented organizations operated in grocery, fashion, electronics, general retail, and other retail segments.

Table 1. Characteristics of respondents and represented retail organizations.

Category	Frequency	Percentage (%)
Respondent Characteristics		
Gender		
Male	201	55.37
Female	162	44.63
Total	363	100
Age Group		
18–24 years	52	14.33
25–34 years	138	38.02
35–44 years	117	32.23
45 years and above	56	15.42
Total	363	100
Educational Level		
Secondary education	41	11.29
Bachelor's degree	176	48.48
Master's degree	121	33.33
Doctoral degree	25	6.90
Total	363	100
Professional Field		
Retail Operations	104	28.65
Business/Marketing	87	23.97
Digital Services/E-commerce	118	32.51
Information Technology	39	10.74
Other	15	4.13
Total	363	100
Respondent position		
Senior management	65	17.91
Middle management	88	24.24
Specialist	210	57.85
Total	363	100
Role in digital transformation		
Decision-maker	135	37.19
Technical specialist	108	29.75
Operational user	120	33.06
Total	363	100
Organizational characteristic		
Retail type		
Grocery	54	14.88
Fashion	149	41.05
Electronics	99	27.27
General retail	39	10.74
Other	22	6.06
Total	363	100

Note: *N* = 363 retail professionals representing 363 distinct retail organizations in Romania. Each respondent was employed in and reported on a different organization.

The sample included respondents with managerial, technical, and operational responsibilities. Overall, 42.15% occupied senior- or middle-management positions, while digital-transformation roles were distributed across decision-making, technical, and op-

erational responsibilities. This profile is consistent with the purposive selection of respondents familiar with organizational digital-transformation practices.

Because all constructs were measured using self-reported data obtained from the same respondents through a single questionnaire, procedural measures were implemented to reduce the potential for common method variance. Participation was voluntary and anonymous, the questionnaire items were formulated in clear and unambiguous language, and the constructs were presented in conceptually separated sections. Harman's single-factor test was conducted as a preliminary diagnostic by entering all 19 measurement items into an unrotated exploratory factor analysis.

The first unrotated factor accounted for 41.59% of the total variance. This result is reported only as a preliminary descriptive diagnostic and does not establish the absence of common method variance. Given the cross-sectional, single-source, and single-respondent nature of the study, common method variance cannot be conclusively ruled out.

The analysis was conducted in two stages. First, descriptive statistics were generated using IBM SPSS Statistics version 27.0 to summarize the characteristics of the respondents and the represented organizations. Second, the conceptual model was estimated using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS 4. PLS-SEM was selected because the proposed model included multiple latent constructs and both direct and indirect associations.

The measurement model was evaluated using indicator loadings, Cronbach's alpha, composite reliability, average variance extracted, and the heterotrait–monotrait ratio. The structural model was assessed using standardized path coefficients, effect sizes, coefficients of determination, predictive relevance, and the standardized root mean square residual. Statistical inference for the direct and indirect associations was based on a bootstrapping procedure with 5000 resamples. Because the data were collected at a single point in time, the estimated direct and indirect effects were interpreted as statistical associations consistent with the proposed model rather than as evidence of causal or temporal sequences.

5. Results

The evaluation of the measurement model does not rely on a single diagnostic criterion but unfolds progressively. Indicator reliability is considered first, followed by internal consistency and convergent validity at the construct level. Such a sequence makes it possible to examine the behavior of individual items before drawing conclusions about the constructs they are intended to represent. The outer loadings presented in Table 2 range from 0.784 to 0.878, exceeding the recommended threshold of 0.70 and indicating satisfactory indicator reliability.

Table 2. Measurement Model—Outer Loadings.

Construct	Item	Loading
DCF	DCF1—Our organization has a well-developed digital infrastructure that supports business operations.	0.812
	DCF2—Digital systems within the organization are well integrated and interoperable.	0.845
	DCF3—The organization effectively uses data analytics to support decision-making processes.	0.867
	DCF4—Employees are able to use digital technologies efficiently in their daily activities.	0.831
	DCF5—The organization continuously invests in upgrading and improving digital technologies.	0.804
ORF	ORF1—Top management actively supports digital transformation initiatives.	0.873
	ORF2—The organization has a clear strategic direction regarding digital transformation.	0.851
	ORF3—Employees are open and adaptable to digital and organizational change.	0.829
	ORF4—The organization has sufficient resources (financial, human, technical) to support digital transformation.	0.806
ESP	ESP1—Regulatory requirements encourage the adoption of sustainable digital practices.	0.798
	ESP2—Customers increasingly expect organizations to adopt sustainable and digital solutions.	0.822
	ESP3—Industry standards and competitors influence the adoption of sustainability-oriented digital initiatives.	0.809
	ESP4—Environmental and ESG pressures motivate the organization to invest in digital transformation.	0.784
SDTA	SDTA1—The organization actively evaluates digital solutions for sustainability purposes.	0.861

SDTA2—Sustainability considerations are integrated into digital transformation strategies.	0.878
SDTA3—Digital technologies are used to improve environmental performance.	0.845
SDTA4—The organization has implemented digital solutions that support sustainable operations.	0.832
SDTA5—Digital transformation initiatives contribute to long-term sustainability goals.	0.817
SDTA6—The organization continuously adopts new digital solutions to enhance sustainability outcomes.	0.804

Building on the satisfactory performance of the individual measurement items, the analysis moves to a more aggregated level, where internal consistency and convergent validity of the latent constructs are examined in greater detail. This step serves to verify not only the individual adequacy of the indicators, but also the extent to which they jointly reflect the underlying theoretical dimensions in a coherent and reliable way. The corresponding results are reported in Table 3.

Table 3. Reliability and Convergent Validity.

Construct	Cronbach's Alpha	Composite Reliability (CR)	AVE
DCF	0.902	0.927	0.718
ORF	0.871	0.912	0.721
ESP	0.845	0.897	0.686
SDTA	0.914	0.933	0.699

Cronbach's alpha values point, overall, to a high level of internal consistency across the constructs included in the model. Perceived sustainable digital transformation adoption (SDTA) records the highest value ($\alpha = 0.914$), which indicates a very strong level of reliability. Digital capability (DCF) follows closely ($\alpha = 0.902$), while organizational readiness (ORF) reaches a slightly lower, though still robust, level ($\alpha = 0.871$). For external sustainability pressures (ESP), the coefficient is somewhat lower ($\alpha = 0.845$); even so, it remains above the commonly accepted threshold, which suggests that the construct can still be regarded as reliable.

A similar pattern becomes visible when composite reliability (CR) is considered. Since CR takes into account the contribution of individual indicator loadings, it often provides a more nuanced view of internal consistency. In this case, all constructs exceed the recommended value of 0.70, with observed values ranging between 0.897 and 0.933. SDTA again stands out (CR = 0.933), followed by DCF (CR = 0.927), ORF (CR = 0.912), and ESP (CR = 0.897). While the differences are not substantial, the overall picture remains consistent, pointing to a measurement structure that is stable across constructs.

Convergent validity was examined through the average variance extracted (AVE). The values are, in all cases, above the 0.50 threshold, although they are not identical across constructs. ORF (0.721) and DCF (0.718) reach the highest levels, which indicates a somewhat stronger ability to capture the variance of their indicators. For SDTA (0.699) and ESP (0.686), the values are lower, but not to a problematic extent.

Turning to discriminant validity, the HTMT ratios reported in Table 4 remain below the conservative threshold of 0.90. This indicates that the constructs are sufficiently distinct from one another at the empirical level, even if some degree of association between them is to be expected given the structure of the model.

Table 4. Heterotrait–Monotrait ratio (HTMT).

	DCF	ORF	ESP	SDTA
DCF	1.000			
ORF	0.742	1.000		
ESP	0.658	0.701	1.000	
SDTA	0.776	0.812	0.645	1.000

The highest HTMT ratio is observed between ORF and SDTA (HTMT = 0.812). Because the value remains below the 0.90 threshold, it supports discriminant validity between organizational readiness and perceived adoption, although this construct pair records the highest HTMT ratio in the measurement model.

The HTMT ratio between digital capability and perceived adoption is 0.776. This value also remains below the 0.90 threshold and supports discriminant validity between DCF and SDTA. The result indicates that the constructs are empirically distinguishable, despite their conceptual relationship within the model.

The HTMT ratio between DCF and ORF is 0.742. Because the value remains below the 0.90 threshold, it supports the empirical distinctness of digital capability and organizational readiness, despite their conceptual relationship within the model.

Moreover, the HTMT ratios involving external sustainability pressures are 0.658 with DCF, 0.701 with ORF, and 0.645 with SDTA. All values remain below the 0.90 threshold and support the empirical distinctness of ESP from the other constructs. The structural relationships involving ESP are examined separately through the path and specific indirect-effect analyses.

The explanatory power of the model was assessed using the coefficient of determination (R^2). As reported in Table 5, the R^2 values are 0.634 for SDTA, 0.512 for ORF, and 0.081 for DCF. According to the applied interpretation, explanatory power is moderate for SDTA and ORF and weak for DCF. The lower R^2 for DCF is consistent with the model specification, in which ESP is its only predictor.

Table 5. Coefficient of determination (R^2).

Construct	R^2	Interpretation
DCF	0.081	Weak
ORF	0.512	Moderate
SDTA	0.634	Moderate

The coefficient of determination (R^2) offers a first indication of how much variance the model is able to explain, but it does not fully capture its predictive side. For this reason, predictive relevance was also examined using the Stone–Geisser Q^2 indicator, obtained through the blindfolding procedure.

All Q^2 values are above zero, indicating predictive relevance for the endogenous constructs. DCF shows small predictive relevance, whereas ORF and SDTA show medium predictive relevance according to the applied thresholds (Table 6). This distribution of results is consistent when considered in light of the model structure. Given that DCF is positioned as an endogenous construct mainly influenced by external sustainability pressures, its lower predictive contribution is consistent with the way the relationships are specified.

Table 6. Predictive Relevance (Q^2).

Construct	Q^2	Interpretation
DCF	0.090	Small
ORF	0.320	Medium
SDTA	0.410	Medium

Overall model fit was also examined using the standardized root mean square residual (SRMR). The reported value (SRMR = 0.062) remains below the commonly accepted threshold of 0.08. This suggests that the model fit can be considered adequate, even if such indicators should not be interpreted in isolation. In practical terms, the result does not raise concerns regarding the specification of the structural model.

To assess the significance and strength of the hypothesized relationships, bootstrapping with 5000 resamples was applied [22]. Figure 2 provides an overview of the structural paths included in the model.

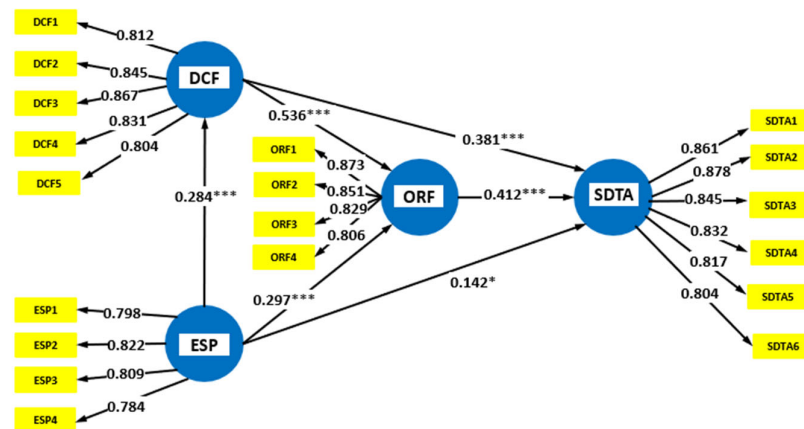


Figure 2. Structural model with standardized path coefficients. Note: *** $p < 0.001$; * $p < 0.05$.

The structural model results reported in Table 7 indicate that all hypothesized associations are statistically supported in the present sample, although their magnitudes vary.

Table 7. Structural Model Results.

Hypothesis	Path	β	t -Value	p -Value	Result
H1	ORF $\rightarrow$ SDTA	0.412	7.89	<0.001	Supported
H2	DCF $\rightarrow$ ORF	0.536	10.12	<0.001	Supported
H3	DCF $\rightarrow$ SDTA	0.381	6.94	<0.001	Supported
H4	ESP $\rightarrow$ ORF	0.297	4.85	<0.001	Supported
H5	ESP $\rightarrow$ SDTA	0.142	2.11	0.035	Supported (small effect)
H6	ESP $\rightarrow$ DCF	0.284	4.63	<0.001	Supported

The relationship between digital capability (DCF) and organizational readiness (ORF) stands out in the model ($\beta = 0.536$, $p < 0.001$). This is the largest standardized path coefficient among the hypothesized relationships and indicates a close positive association between the two constructs without implying conceptual overlap.

Organizational readiness shows a clear positive association with perceived sustainable digital transformation adoption (SDTA) ($\beta = 0.412$, $p < 0.001$). Digital capability also maintains a positive direct association with SDTA ($\beta = 0.381$, $p < 0.001$), although the coefficient is slightly smaller. Taken together, these results show that both internal constructs have substantial direct associations with perceived adoption.

External sustainability pressures show a statistically significant but comparatively small direct association with perceived sustainable digital transformation adoption ($\beta = 0.142$, $p = 0.035$). ESP is also positively associated with organizational readiness ($\beta = 0.297$, $p < 0.001$) and digital capability ($\beta = 0.284$, $p < 0.001$). As reported in Table 8, the corresponding effect sizes are small. Thus, ESP has a more limited direct association with perceived adoption than the two internal constructs, while also being associated with both organizational readiness and digital capability.

The effect-size analysis reported in Table 8 provides additional context for interpreting these relationships beyond statistical significance. Specifically, the effect sizes are small for ESP $\rightarrow$ ORF ($f^2 = 0.112$), ESP $\rightarrow$ DCF ($f^2 = 0.095$), and ESP $\rightarrow$ SDTA ($f^2 = 0.028$), whereas the effects associated with the internal constructs are larger.

Table 8. Effect sizes (f^2).

Path	f^2	Interpretation
DCF → ORF	0.402	Large
ORF → SDTA	0.268	Medium
DCF → SDTA	0.231	Medium
ESP → ORF	0.112	Small
ESP → DCF	0.095	Small
ESP → SDTA	0.028	Small

The largest effect size among the examined relationships is observed for the association between digital capability and organizational readiness ($f^2 = 0.402$). This large effect size indicates that DCF makes a substantial contribution to the explained variance of ORF within the specified model, without establishing a causal relationship.

For the paths leading directly to perceived sustainable digital transformation adoption, both ORF → SDTA ($f^2 = 0.268$) and DCF → SDTA ($f^2 = 0.231$) have medium effect sizes. These results indicate that both organizational readiness and digital capability make meaningful direct contributions to the explanatory power of the model for perceived adoption.

A different pattern is observed for external sustainability pressures. The effect sizes for ESP → ORF ($f^2 = 0.112$) and ESP → DCF ($f^2 = 0.095$) are small, as is the direct effect size for ESP → SDTA ($f^2 = 0.028$). These results indicate that ESP makes smaller individual contributions to the endogenous constructs than the internal predictors make to ORF and SDTA. The effect-size results alone do not establish that ESP facilitates the development of internal capabilities.

Taken together, the distribution of effect sizes shows that the paths involving digital capability and organizational readiness have larger effect sizes than the paths originating from external sustainability pressures. This pattern complements the standardized path coefficients and supports the interpretation that the internal constructs are more strongly associated with perceived adoption within the specified model.

A more detailed understanding of the structural relationships is provided by the analysis of the specific indirect effects reported in Table 9. The results show statistically significant indirect associations between external sustainability pressures and perceived adoption through digital capability and organizational readiness, alongside the small but statistically significant direct association.

Table 9. Specific indirect effects of external sustainability pressures on perceived adoption.

Path	Indirect Effect	t-Value	p-Value
ESP → ORF → SDTA	0.122	4.01	<0.001
ESP → DCF → SDTA	0.108	3.76	<0.001
ESP → DCF → ORF → SDTA	0.063	3.12	0.002

Looking more closely at the indirect effects, the pathway ESP → ORF → SDTA shows a statistically significant indirect effect of 0.122 ($p < 0.001$). This result indicates that the relationship between ESP and perceived adoption includes an indirect component through organizational readiness, alongside the small but statistically significant direct association.

A comparable pattern is observed for the pathway ESP → DCF → SDTA, indicating a statistically significant indirect association between external sustainability pressures and perceived adoption through digital capability. This result does not establish that external pressures caused technological improvements or that such improvements occurred before adoption.

The sequential pathway $ESP \rightarrow DCF \rightarrow ORF \rightarrow SDTA$ is also statistically significant. This result is consistent with the theoretically specified model linking external sustainability pressures to perceived adoption through digital capability and organizational readiness. Given the cross-sectional design, the estimate should not be interpreted as evidence that the constructs change in the temporal order represented by the model or as confirmation of a multi-stage capability-development process.

The results show a small but statistically significant direct association between external sustainability pressures and perceived adoption ($\beta = 0.142, p = 0.035$), alongside significant specific indirect associations through organizational readiness, through digital capability, and through the sequential $ESP \rightarrow DCF \rightarrow ORF \rightarrow SDTA$ pathway. The coexistence of statistically significant direct and indirect associations is consistent with partial mediation in the specified model. These indirect associations should not be interpreted as evidence of causal or temporal mechanisms.

6. Discussion

Reported levels of perceived sustainable digital transformation adoption vary across retail organizations and are associated with technological, organizational, and environmental conditions. The findings are consistent with prior research emphasizing the role of internal capabilities in digital transformation [4,14,26] and differ from studies reporting stronger direct associations between environmental pressures and adoption [29,41,59,63]. In the present study, organizational readiness and digital capability show larger direct associations with perceived adoption than external sustainability pressures, while the significant specific indirect associations are consistent with a capability-mediated interpretation.

The close but empirically distinct relationship between digital capability and organizational readiness supports their treatment as complementary internal conditions rather than as a single construct. From a capability-based perspective, this pattern is consistent with the view that technological capacity and organizational preparedness are related but analytically distinct components of organizational transformation [14,59].

The organizations examined operate within a shared Romanian national and retail-sector context. This common context does not establish that external pressures were perceived similarly across organizations, because environmental homogeneity was not directly measured.

From a TOE perspective, the findings distinguish between a direct-effects environmental account and a capability-mediated account. A direct-effects account would assign a prominent role to the direct association between environmental pressures and adoption [13,46]. In the present study, this association remains statistically significant, but its small magnitude and p -value close to the conventional significance threshold require cautious interpretation and replication. The significant indirect associations are more consistent with a capability-mediated account [14]. Because the direct association remains significant, the two interpretations are complementary rather than mutually exclusive.

Regarding RQ1, perceived sustainable digital transformation adoption is more strongly associated with organizational readiness and digital capability than with external sustainability pressures. This pattern gives greater explanatory relevance to the technological and organizational dimensions of TOE within the Romanian retail sample, while indicating that the environmental dimension remains relevant. The result is consistent with a capability-oriented interpretation in which internal technological capacity and organizational preparedness are closely associated with perceived adoption. This interpretation is context-specific and does not imply causal priority or environmental homogeneity.

Regarding RQ2, the findings indicate significant specific indirect associations between external sustainability pressures and perceived adoption through organizational readiness, through digital capability, and via the specified $ESP \rightarrow DCF \rightarrow ORF \rightarrow SDTA$ path. Together with the significant direct association, this pattern is consistent with partial mediation.

Viewed as a whole, the findings indicate that perceived sustainable digital transformation adoption is associated with all three TOE dimensions represented in the model. The theoretical contribution lies in showing that a direct environmental-pressure explanation and a capability-mediated explanation can coexist: external sustainability pressures retain a small direct association with perceived adoption, while digital capability and organizational readiness are involved in significant indirect associations. This provides a context-specific extension of TOE for Romanian retail without implying that the statistical paths represent verified organizational mechanisms or objectively measured sustainability performance.

7. Conclusions

This study examined the direct and specific indirect associations among external sustainability pressures, digital capability, organizational readiness, and perceived sustainable digital transformation adoption in Romanian retail organizations. Organizational readiness and digital capability showed larger direct associations with perceived adoption than external sustainability pressures. External sustainability pressures nevertheless retained a small statistically significant direct association and significant indirect associations through the internal constructs.

The findings provide an incremental, context-specific extension of the TOE framework. They are consistent with the coexistence of a direct environmental-pressure explanation, reflected in the direct association of external sustainability pressures with perceived adoption, and a capability-mediated explanation, reflected in the significant indirect associations through digital capability and organizational readiness. The results also support the empirical distinctness of digital capability, organizational readiness, and perceived adoption rather than treating them as interchangeable dimensions.

Because the study is cross-sectional and based on self-reported perceptions, the estimated paths should not be interpreted as causal mechanisms or temporal sequences. The findings concern perceived sustainable digital transformation adoption and do not establish objectively verified environmental performance, capability development, or long-term transformation outcomes.

7.1. Managerial and Practical Implications

The results suggest that retail managers should not rely on external sustainability pressures alone to support sustainability-oriented digital adoption. The direct $ESP \rightarrow SDTA$ association is statistically significant but small ($\beta = 0.142$; $f^2 = 0.028$), indicating that regulatory, ESG, customer, and competitive pressures are relevant but make a limited direct contribution within the specified model.

Greater managerial attention should be directed toward organizational readiness and digital capability, which show larger direct associations with perceived adoption and medium effect sizes. In practical terms, managers should strengthen integrated digital infrastructure, analytics, and employee digital competence while also reinforcing strategic direction, top-management support, employee adaptability, and the availability of financial, human, and technical resources. The large $DCF \rightarrow ORF$ effect size further suggests that technological capacity and organizational preparedness should be managed as closely related but distinct areas.

The significant indirect associations suggest that sustainability-oriented policies and market signals may be more useful when accompanied by internal technological and organizational conditions capable of supporting adoption. This implication should be treated as guidance derived from the model rather than as proof of a fixed implementation sequence. Managers should therefore assess both technological capability and organizational preparedness while avoiding the assumption that compliance pressure alone will produce sustainable digital transformation.

7.2. Limitations and Future Research

Several limitations should be considered when interpreting the findings. They concern the cross-sectional design, the self-reported and single-source data, the non-probability sample, the restricted organizational information available, and the single-country retail context.

The cross-sectional design captures the relationships at a single point in time and cannot assess their temporal direction, development, or stability across measurement occasions. Longitudinal data are needed to determine whether the observed associations remain stable across subsequent observations.

The results are based on respondents' assessments of organizational capabilities, external pressures, and adoption rather than on independently verified organizational or environmental outcomes. Because one respondent reported on each organization, within-organization agreement could not be assessed. In addition, all constructs were measured through the same questionnaire and reported by the same respondent. Although procedural measures were implemented and Harman's single-factor test was conducted as a preliminary diagnostic, common method variance cannot be conclusively ruled out.

The study is limited to retail organizations operating in Romania. Although the organizations share a national and sectoral setting, environmental homogeneity was not directly measured. The findings should therefore not be interpreted as evidence that the organizations experienced equivalent regulatory, ESG, competitive, or customer pressures. Research conducted in other countries, sectors, and institutional environments is needed to assess the generalizability of the observed relationships.

The available data did not include organization size, ownership structure, objective digitalization or digital-maturity indicators, supply-chain position, or respondent tenure within the organization. These characteristics could be associated with digital capability, organizational readiness, exposure to sustainability pressures, and perceived adoption. Their absence limits the possibility of assessing organizational heterogeneity or controlling for alternative explanations. Future studies should include these characteristics as control variables, moderators, or bases for multigroup analysis.

The purposive non-probability sampling strategy also limits statistical generalization beyond the examined respondents and organizations. Although the participants were selected because of their involvement in digital transformation activities, the sample should not be treated as representative of all Romanian retail organizations. Future research could use probability-based sampling frames or replicate the model in independently recruited samples.

The positive association between digital capability and organizational readiness does not establish the temporal direction of their relationship. The specified DCF → ORF path reflects the theoretical model, but alternative or reciprocal relationships cannot be excluded using cross-sectional data. Longitudinal and cross-lagged designs are needed to examine temporal ordering and reciprocal development.

Future research should test the proposed model using longitudinal and multi-source designs in independently recruited samples. Such studies could examine the stability and direction of the observed associations, reduce reliance on single-respondent perceptions,

and assess whether the findings generalize beyond the Romanian retail context. The inclusion of objective organizational and sustainability indicators would also provide a stronger basis for evaluating sustainable digital transformation outcomes.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
AVE	Average Variance Extracted
CR	Composite Reliability
DCF	Digital Capability
ESG	Environmental, Social, and Governance
ESP	External Sustainability Pressures
f^2	Effect Size
HTMT	Heterotrait–Monotrait Ratio
IBM SPSS	International Business Machines Statistical Package for the Social Sciences
IT	Information Technology
ORF	Organizational Readiness
PLS-SEM	Partial Least Squares Structural Equation Modeling
Q^2	Stone–Geisser Predictive Relevance
R^2	Coefficient of Determination
SDT	Sustainable Digital Transformation
SDTA	Perceived Sustainable Digital Transformation Adoption
SRMR	Standardized Root Mean Square Residual
TOE	Technology–Organization–Environment

Appendix A

Table A1. Literature basis and operational focus of the measurement items.

Construct	Code	Literature Basis	Operational Focus
Digital Capability	DCF1	[14,39,46]	Operationalizes the TOE technological dimension through organization-level digital infrastructure in retail.
	DCF2	[34,53,60]	Focuses on system integration and interoperability in digitally enabled operations.
	DCF3	[32,42,60,61]	Reflects the organizational use of data analytics in operational and managerial decision-making.
	DCF4	[1,14,52]	Represents employee digital competence in routine work activities.
	DCF5	[14,46,59]	Addresses continued organizational investment in digital renewal and capability strengthening.
Organizational Readiness	ORF1	[14,46,52]	Reflects top-management support for digital transformation in retail organizations.
	ORF2	[1,30,46]	Represents the strategic-direction component of organizational readiness.
	ORF3	[1,2,59]	Addresses employee adaptability and openness to digital and organizational change.
	ORF4	[14,46,52,59]	Covers the financial, human, and technical resources required for digital transformation.
External Sustainability Pressures	ESP1	[36,37,46,52]	Operationalizes regulatory and institutional pressure in the context of sustainable digital practices.
	ESP2	[16,18,19,52]	Represents customer expectations at the intersection of sustainability and digitalization.
	ESP3	[40,46,50,52]	Combines competitive pressure and industry standards in relation to sustainability-oriented digital initiatives.
	ESP4	[18,19,35–37,45,48]	Reflects environmental, ESG, and reporting pressures associated with digital-transformation investment.
Perceived Sustainable Digital Transformation Adoption	SDTA1	[6,16,21,39]	Represents the evaluation stage of sustainability-oriented digital adoption.
	SDTA2	[6,16,21,55,59]	Addresses the strategic integration of sustainability into digital transformation.
	SDTA3	[7,8,17,60]	Reflects the perceived use of digital technologies for environmental objectives.
	SDTA4	[21,54,59,60]	Represents reported implementation of digital solutions supporting sustainable operations.
	SDTA5	[6,35–37,55]	Addresses perceived alignment between digital initiatives and long-term sustainability goals.
	SDTA6	[1,3,16,39,46]	Represents the continuation of sustainability-oriented digital adoption.

Note: The complete wording and outer loadings of the measurement items are reported in Table 2. All items were developed by the authors based on the construct domains identified in the cited literature and were contextualized for sustainability-oriented digital transformation in retail organizations. The cited studies provide the conceptual and empirical basis for the item domains and are not presented as sources of verbatim item wording. DCF = digital capability; ORF = organizational readiness; ESP = external sustainability pressures; SDTA = perceived sustainable digital transformation adoption.

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