Journal of Innovation & Knowledge xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Innovation & Knowledge

journal homepage: www.elsevier.com/locate/jik

Rethinking ESG-driven innovation in early-stage digital startups

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ARTICLE INFO

JEL codes:
O32
L26
M14
D83
Q56

Keywords:
Digitalised startups
ESG disclosure
Knowledge assets
Industry context
Sustainable growth

ABSTRACT

Prevailing narratives suggest that ESG disclosure in startups fuels innovation and growth, yet most evidence comes from large, established firms. This paper examines how industry context, codified knowledge assets, and website-based ESG disclosure intensity are associated with revenue and employment growth in early-stage European digitalised startups with stable online footprints and complete linked data. Using a knowledge-based and industry-context framework, we treat sector-level opportunity and codified knowledge assets as the primary structural and firm-level conditions, and website-based ESG disclosure intensity as a comparatively low-cost, potentially weak signal. The empirical analysis draws on a two-tier design: a broader frame of 2465 European digitalised startups and a selected analytical sample of 144 ventures for which archived website text, a composite measure of codified knowledge assets, mapped OECD sector-level contextual proxies, and five-year growth outcomes are available. In this selected analytical sample, codified knowledge assets are consistently and positively associated with both revenue and employment growth. In contrast, the sector-level contextual proxy is positively associated only with employment growth. By contrast, website-based ESG disclosure intensity shows no robust direct association with either growth outcome nor a strong baseline association with codified knowledge. The study offers boundary-setting evidence on ESG-growth relationships in early-stage digitalised startups with observable website disclosure. In this setting, industry context and codified knowledge assets dominate the observed short-term growth associations, whereas website-based ESG disclosure intensity functions as a low-cost signal with limited observable short-term implications.

Introduction

Over the past decade, growing environmental degradation, climate change, and social inequalities have pushed corporate sustainability to the forefront of policy, managerial, and innovation agendas. In Europe, the European Green Deal and the global commitment to the United Nations Sustainable Development Goals (SDGs) have catalysed this transformation. Within this context, startups and innovation-driven enterprises increasingly communicate environmental, social, and governance priorities as part of their effort to build legitimacy, secure capital, and position themselves within sustainability-oriented ecosystems (Hellemans et al., 2022; Grybauskas et al., 2022).

While website-based ESG disclosure and related reporting practices have become central themes in corporate sustainability research, their role and relevance to growth within startup ecosystems remain insufficiently understood. The prevailing theoretical narrative suggests that ESG disclosure, including website-based ESG disclosure intensity, should be positively associated with growth through knowledge-related channels and the development of innovation capacity. However, startups differ fundamentally from established firms: they face severe resource constraints, operate under short time horizons, and have pronounced information asymmetries (Ahlstrom & Bruton, 2010; Drover et al., 2017), which may limit their ability to convert website-based ESG disclosure into observable short-term performance gains. This gap between theoretical expectations and empirical reality motivates our research question: are industry context, codified knowledge assets, and website-based ESG disclosure intensity associated with short-term startup growth trajectories, and, if so, under what conditions does ESG disclosure make an incremental contribution beyond industry context and knowledge assets? This study provides boundary-setting evidence

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https://doi.org/10.1016/j.jik.2026.101140
Received 24 December 2025; Accepted 11 August 2026

on when website-based ESG disclosure intensity is and is not associated with short-term growth in early-stage digitalised startups for which website disclosures are available. Startups play a pivotal role in Europe's innovation-driven economies. Digital technologies have transformed startup operations by enabling rapid access to global markets and knowledge networks (Nambisan, 2017; Nambisan et al., 2019), making website-based ESG disclosure more feasible through accessible data collection and stakeholder communication platforms (Feroz et al., 2021). However, startups lack the codified routines and accumulated knowledge of established firms, requiring the rapid development of dynamic capabilities and absorptive capacity (Zahra et al., 2006).

Moreover, startups operate within distinct industry contexts that may condition the observed performance outcomes. Institutional theory posits that industry-level institutional fields create divergent environments for firm growth through sector-specific regulations, normative pressures, and resource configurations (DiMaggio & Powell, 1983; Aragon-Correa & Sharma, 2003). Resource Dependence Theory explains how sectoral resource networks constrain individual firm growth prospects (Pfeffer & Salancik, 1978; Hillman et al., 2009). Stakeholder salience varies systematically across industries (Mitchell et al., 1997; Agle et al., 1999). These broader sectoral conditions-approximated here by observable patterns of average industry-level growth derived from OECD data-may account for some of the variation in startup revenue and employment growth, potentially reducing the incremental explanatory contribution of firm-level website-based ESG disclosure intensity.

A particular challenge confronting startup ESG research concerns measurement. Formal sustainability certification remains rare among small firms due to substantial structural barriers (Parker et al., 2019; Asma-Arikan et al., 2024; Attanasio et al., 2025), and established ESG rating systems exhibit documented bias that favours large businesses (Orlitzky, 2001; Drempetic et al., 2020; Berg et al., 2022; Mansouri & Momtaz, 2022; Fichter et al., 2023). We therefore operationalise the focal construct as website-based ESG disclosure intensity, derived from startups' publicly available website text and voluntary sustainability-related disclosures. Institutional and legitimacy perspectives suggest that firms may publicly disclose information to signal conformity with emerging sustainability expectations (DiMaggio & Powell, 1983; Suchman, 1995; Wang et al., 2018; Deegan, 2019; Lee et al., 2024). Abraham et al. (2024) validate communication-based ESG measures, demonstrating that website disclosure can serve as a usable proxy for ESG disclosure salience while remaining distinct from direct measures of operational ESG practice, particularly following the 2015 Paris Agreement.

The research described here seeks to answer the following question: How are industry context, codified knowledge assets, and website-based ESG disclosure intensity associated with revenue and employment growth in early-stage digitalised European startups, and under what sectoral conditions does website-based ESG disclosure intensity make an incremental contribution beyond industry context and codified knowledge assets? We examine this question using an empirical setting of European digitalised startups for which archived website text, codified knowledge assets, mapped sector-level contextual indicators, and growth outcomes are all observable, thereby focusing on ventures with stable website disclosure and complete linked data.

To address the research question, we anchor our argument primarily in the Knowledge-Based View (KBV) and industry-context logic, and we draw on signalling, stakeholder, and resource-dependence perspectives as supporting lenses (Nonaka, 1994; Nonaka & Takeuchi, 1995; Grant, 1996) to interpret how industry context, codified knowledge assets, and website-based ESG disclosure intensity are associated with startup growth trajectories. The Knowledge-Based View serves as the primary theoretical lens, positioning codified knowledge assets, including patents and other formal knowledge outputs, as salient firm-level resources from which competitive advantage may be derived, while recognising that these assets operate within industry contexts that establish structural opportunity sets.

We formulate five hypotheses within a boundary-setting framework that emphasises industry context and codified knowledge assets, alongside website-based ESG disclosure intensity:

- H1: Industry context as a sector-level condition associated with growth opportunities
- H2: Codified knowledge assets as the firm-level differentiator within those structural constraints
- H3: Website-based ESG disclosure intensity as a weaker short-term signal
- H4: Sectoral context as a possible boundary condition for ESG disclosure associations
- H5: Exploratory test of the relationship between ESG disclosure and codified knowledge assets as a potential pathway.

Together, the hypotheses provide an analytical ordering: industry context as the sector-level growth condition that determines growth opportunities; codified knowledge assets as the firm-level differentiator within those constraints; and website-based ESG disclosure intensity as a conditional mechanism whose short-term associations may be weak or contingent on sectoral innovation intensity and knowledge creation capacity.

To test these hypotheses, we employ quantitative cross-sectional data analysis of 2465 European startups (2017–2021), integrating ESG indicators, growth metrics, and measures of innovation and IP generation. Our empirical strategy employs cross-sectional ordinary least squares (OLS) regressions and interaction models, and auxiliary tests of ESG disclosure-codified knowledge asset associations, incorporating lagged ESG variables and robustness checks.

This study makes three contributions. First, we provide empirical boundary-setting evidence on ESG disclosure-growth relationships in early-stage European digitalised startups with stable, observable website-based disclosure and complete data, clarifying where the assumed short-term ESG-growth associations do not materialise. We show that in this setting, industry context and codified knowledge assets are most strongly associated with short-term growth, while website-based ESG disclosure intensity functions as a conditional and often limited contributor. We identify critical boundary conditions that clarify where and why website-based ESG disclosure may not consistently exhibit the short-term growth associations commonly assumed in the entrepreneurial sustainability literature.

Second, methodologically, we develop dictionary-based ESG disclosure scores from public digital communication channels, thereby addressing a limitation of certification-based measures, which are underrepresented in early-stage ventures.

Third, empirically, we quantify the relative importance of industry context, knowledge assets, and ESG disclosure as correlates of startup growth. We show that in early-stage European digitalised startups with stable website disclosure, industry context and codified knowledge assets are stronger predictors of short-term revenue and employment growth. In contrast, website-based ESG disclosure intensity is at best a weak, context-dependent signal that is associated with observable short-term variation in performance.

Theoretical background

This study's theoretical foundation rests on the knowledge-based view (KBV) and related resource-based arguments, which position codified knowledge assets as central strategic resources that drive competitive advantage (Grant, 1996; Nonaka & Takeuchi, 1995). The framework integrates three levels: industry structures that condition growth opportunities, firm-level codified knowledge assets that may help explain differences among firms in relation to those industry conditions, and website-based ESG disclosure intensity, which may provide an additional signal. The analytical sequence is explicit: industry context is treated as the antecedent sector-level condition, codified knowledge

assets differentiate firms within those industry conditions, and website-based ESG disclosure intensity is theorised as a signal whose short-term relevance may be limited once industry and codified knowledge assets are taken into account. The Knowledge-Based View and industry-structure analysis provide the primary theoretical framework. Signalling theory provides the specific logic for why disclosure-based signals may differ in strength from codified knowledge assets, while stakeholder and resource-dependence perspectives help explain why these relationships may vary across sectors. This analytical sequence reflects the expectation that structural and knowledge-based factors are likely to be more salient for early-stage venture growth than disclosure-based signals.

Industry context and growth conditions

Industry context represents the first level of the analytical framework for explaining variation in startup growth trajectories. Sectoral opportunity structures (encompassing observable sector-level growth conditions and related innovation environments, including demand growth, technological dynamism, and resource conditions that are only imperfectly captured by available sector-level indicators) create divergent growth environments that may condition firm-level performance independent of firm-specific capabilities. In this study, these broader structural characteristics are approximated through observable patterns of average industry-level growth derived from external OECD sector-level indicators, which serve as contextual proxies for underlying demand dynamics, technological trajectories, and resource availability.

Cohen and Levinthal's (1990) absorptive capacity framework proposes that industry-level knowledge infrastructures condition firms' ability to recognise, assimilate, and exploit external knowledge. The sectoral innovation systems literature specifies that industries differ systematically in technological opportunity structures, appropriability conditions, and knowledge bases, creating institutional configurations that fundamentally shape innovation processes and growth potential (Malerba, 2002; Castellacci, 2008).

Resource dependence theory posits that firms are embedded within sectoral resource networks, with industry-level resource configurations constraining the growth prospects of individual firms (Pfeffer & Salancik, 1978; Hillman et al., 2009). High-growth sectors attract disproportionate venture capital investment, specialised talent, and supportive infrastructure. These sectoral resource flows manifest in observable differences in average industry-level growth rates: sectors with stronger growth conditions may offer more favourable baseline environments for individual firms, regardless of the latter's firm-specific strategies.

Innovation drivers are sector-specific rather than universally applicable. Digitalisation processes operate differently across industries, with technology-intensive sectors exhibiting greater absorptive capacity for digital transformation (Nambisan et al., 2019; Hellemans et al., 2022). Knowledge creation incentives vary systematically across industries, with high-innovation sectors offering stronger appropriability conditions (Malerba, 2002). Sectoral innovation intensity-the degree to which industries exhibit high R&D investment, technological complexity, and knowledge-based competition-serves here as a sectoral knowledge-regime proxy that may condition whether disclosure-related routines correspond to codified knowledge outputs (Castellacci, 2008).

While industry context establishes structural growth opportunities, within these sectoral opportunity structures, codified knowledge assets are expected to differentiate firms within the same broad sectoral conditions. Industry context creates the baseline growth environment, while codified knowledge assets may help explain which firms perform better within that environment. Accordingly, **H1:** Startups operating in industries with stronger sector-level growth conditions, proxied by external industry-level indicators, will exhibit higher revenue and employment growth than startups in industries with weaker sector-level growth conditions, controlling for firm-level characteristics including website-based ESG disclosure intensity and codified knowledge assets.

Codified knowledge assets as firm-level differentiators

The second component of the framework concerns codified knowledge assets. The Knowledge-Based View posits that knowledge is the fundamental strategic resource, with competitive advantage derived from superior capabilities in creating, integrating, and deploying knowledge assets (Nonaka & Takeuchi, 1995; Grant, 1996).

Codified knowledge assets, including patents and other formal knowledge outputs, may serve dual functions, explaining their association with startup growth. As embodiments of knowledge creation, such assets represent formalised innovation activity and knowledge-creation outcomes (Griliches, 1990; Nagaoka et al., 2010; Acs et al., 2002). As signalling mechanisms, they communicate quality and competitive strength to external stakeholders under information asymmetry (Spence, 1973; Connelly et al., 2011). Within the broader set of codified knowledge assets, patents in particular satisfy three key signal characteristics: observability through patent databases, costliness due to R&D investment requirements, and credibility arising from patent office examination, which verifies novelty and utility.

For startups facing severe information asymmetries, patents function as particularly valuable signals (Drover et al., 2017). Venture capitalists may employ patent-based indicators, alongside other codified outputs, as a screening mechanism, with patent counts positively associated with funding acquisition and valuation premiums. Patents enable the appropriation of innovation rents through exclusionary rights, reducing competitive imitation.

Digital platforms may increase the visibility and commercial reach of codified knowledge assets. Digital technologies reduce signalling costs by enabling the instantaneous dissemination of patent information to global stakeholder networks (Nambisan et al., 2019). Digitalisation can support the commercialisation of knowledge across distributed markets, allowing IP-rich startups to leverage their knowledge assets (Feroz et al., 2021). Digital tools enhance knowledge management capabilities-such as real-time data capture, automated analytics, and collaborative platforms- supporting more effective IP generation and exploitation (Fang, 2024). In contemporary digitalised ecosystems, codified knowledge assets may therefore become more visible and easier to mobilise.

From a knowledge-based perspective, codified knowledge assets function as salient strategic resources in technology-driven startup ecosystems, as they simultaneously embody valuable knowledge, credibly signal quality, and can be leveraged through digital platforms to achieve a competitive advantage. Codified knowledge assets represent observable indicators of formal knowledge creation that may be associated with startup growth, regardless of origin, whether generated through ESG-related initiatives, digital transformation, or conventional R&D. Accordingly, **H2**: The volume of a startup's codified knowledge assets is positively associated with its revenue and employment growth after controlling for industry context and website-based ESG disclosure intensity.

Website-based ESG disclosure intensity as a signal

Website-based ESG disclosure intensity is the third component of the framework, but it is contingent and limited in early-stage ventures. Prior theoretical perspectives suggest multiple pathways through which ESG disclosure may positively influence performance: signalling theory predicts that website-based ESG disclosure builds legitimacy and facilitates access to resources, while organisational learning theory and the Knowledge-Based View suggest that the practices underlying the intensity of website-based ESG disclosure may be associated with knowledge-creation processes. However, these theoretical mechanisms are subject to substantial constraints in early-stage, resource-constrained startups, where ESG disclosure may be too recent, too symbolic, or too weakly institutionalised to translate into observable short-term

growth outcomes. H3 thus tests whether website-based ESG disclosure intensity exhibits a positive short-term association with growth once industry context and codified knowledge assets are taken into account, and whether any such association is weaker than that of codified knowledge assets.

Signalling theory predicts that ESG disclosure in startups may build legitimacy with stakeholders under information asymmetry (Connelly et al., 2011). Startups that communicate ESG disclosures through digital channels signal managerial competence, transparency, and attention to sustainability themes (Nishant et al., 2020; Perotti et al., 2024). Digital platforms amplify these signalling dynamics by enabling low-cost, direct communication while increasing stakeholder scrutiny (Deegan, 2019; Boulton, 2024). Institutional theory complements this perspective through highlighting isomorphic pressures that create incentives for firms to present themselves as aligned with emerging sustainability expectations (DiMaggio & Powell, 1983; Lee et al., 2024).

Website-based ESG disclosure intensity is a relatively low-cost signal compared to patents (which require substantial R&D investment and must pass external examination) or sectoral positioning (which reflects inherited structural opportunities). Signalling theory predicts that lower-cost signals are typically weaker and perceived as less credible by sophisticated stakeholders, particularly when they can be easily modified or symbolically adopted without corresponding operational changes (Connelly et al., 2011). Post-2015 Paris Agreement evidence demonstrates that unsupported ESG signals were associated with adverse outcomes, while only substantive communication maintained positive effects (Abraham et al., 2024). In early-stage startups with limited resources and short operating histories, the informational content and perceived credibility of website-based ESG disclosure may be insufficient to generate high-cost signals that meaningfully differentiate ventures in resource markets. This makes the empirical test useful as a boundary-setting exercise: even if disclosure is theoretically relevant, its short-term association may be weak in early-stage ventures.

Organisational learning theory posits that website-based ESG disclosure intensity may be associated with knowledge-related routines in startups (Crossan et al., 1999; Argote & Miron-Spektor, 2011). The Knowledge-Based View posits that competitive advantage derives from the capability of converting tacit insights into explicit, codified knowledge assets (Nonaka & Takeuchi, 1995; Grant, 1996), although this study observes only codified outputs rather than the underlying learning routines themselves. In principle, ESG measurement and reporting in startups may establish deliberate learning mechanisms that generate knowledge persistence (Levinthal & March 1993; Argote et al., 2020). Digital technologies could amplify these learning processes through real-time ESG data capture, automated monitoring, and analytics (Feroz et al., 2021; Wang et al., 2023).

However, multiple theoretical considerations suggest why these learning mechanisms may not materialise as observable short-term growth outcomes in early-stage startups. Website-based ESG disclosure in resource-constrained ventures may be insufficient to satisfy the criteria normally associated with durable competitive advantage: it may be too recent to have become institutionalised, too heterogeneous for stakeholder interpretation, or too weakly integrated into core operations. Resource constraints in early-stage startups limit the depth of ESG institutionalisation, with ventures prioritising product-market fit and technological development over sustainability infrastructure (Zahra et al., 2006). Knowledge management effectiveness depends on whether website-based ESG disclosure intensity is associated with codified knowledge assets-a correspondence many startups fail to achieve (Di Vaio et al., 2021; Riaz et al., 2024). Digitalisation enables ESG communication, but communication does not necessarily translate into substantive ESG practice, and digital visibility may increase scrutiny of symbolic adoption (Feroz et al., 2021; Lim & Hwang, 2026). Given these constraints, H3 tests whether website-based ESG disclosure intensity exhibits a detectable direct association with growth after accounting for stronger structural and knowledge-based factors. Accordingly, **H3**: Once industry context and codified knowledge assets are taken into account, website-based ESG disclosure intensity will be more weakly associated with short-term revenue and employment growth than codified knowledge assets. This expectation is formulated as a boundary-setting probe rather than a strong directional forecast: the study design cannot rule out a null outcome, and the primary purpose of H3 is to test whether the anticipated ordering is empirically detectable in the sample.

Contingency: industry as a boundary condition for ESG disclosure associations

The association between website-based ESG disclosure intensity and startup growth may vary by industry context: sectoral norms, stakeholder configurations, and institutional pressures may condition whether website-based ESG disclosure intensity is associated with performance.

Institutional theory specifies the mechanisms through which industry context moderates the relevance of website-based ESG disclosure intensity (DiMaggio & Powell, 1983). Industries characterised by strong regulatory scrutiny and high consumer visibility create institutional environments where website-based ESG disclosure may become more salient for legitimacy. Conversely, industries with technical rather than consumer-facing products experience weaker institutional pressure. Prior work on proactive environmental strategies suggests that sustainability-related signals and activities are likely to be valued differently across industries (Aragon-Correa & Sharma, 2003).

Stakeholder theory proposes that stakeholder salience varies systematically across industries (Mitchell et al., 1997; Agle et al., 1999), while stakeholder salience theory posits that managers prioritise stakeholders according to power, legitimacy, and urgency. Industries differ in which stakeholder groups possess these attributes and how they weigh ESG disclosure signals in resource allocation decisions (Bridoux & Stoelhorst, 2022).

High-scrutiny sectors face strong stakeholder expectations regarding sustainability performance. In these industries, website-based ESG disclosure intensity may serve as a more salient legitimacy signal, facilitating access to venture capital and partnerships (Bridoux & Stoelhorst, 2022). Consumer-facing platforms operate under heightened scrutiny, making website-based ESG disclosure more visible and potentially more relevant (Grybauskas et al., 2022). Conversely, low-scrutiny sectors prioritise technical differentiation over sustainability attributes, with customers and investors evaluating ventures based on technological capability rather than ESG credentials (Aragon-Correa & Sharma, 2003).

The mechanism operates through industry norms shaping stakeholder resource allocation (Hillman et al., 2009). Innovation mechanisms are sector-specific (Malerba, 2002). Knowledge management priorities vary across industries, with the value of sustainability knowledge differing among sectors (He et al., 2024). Digitalisation manifests differently: digital platforms in consumer sectors emphasise transparency, while enterprise technologies prioritise security, creating distinct ESG communication dynamics (Nambisan et al., 2019; Hellemans et al., 2022).

Industry context and sectoral innovation intensity are examined as possible moderators of the association between website-based ESG disclosure intensity and growth. In sectors with stronger sustainability salience or more knowledge-intensive innovation regimes, website-based ESG disclosure intensity may show a stronger association. However, even in favourable sectoral contexts, moderation effects may remain modest in the short term for early-stage ventures. H4 tests whether contextual amplification is empirically detectable, while recognising that moderation coefficients may be substantively small. Because sectoral innovation intensity is an imperfect proxy for stakeholder scrutiny, the moderation test should be interpreted as a limited exploratory probe rather than a direct test of sustainability pressure.

H4: The association between website-based ESG disclosure intensity and startup revenue and employment growth is moderated by sectoral context, such that the association is stronger in sectors where sustainability-related disclosure is more salient to stakeholders.

Website-based ESG disclosure intensity and codified knowledge assets

If website-based ESG disclosure intensity is associated with startup growth, a related theoretical question is whether it is also associated with codified knowledge assets. Organisational learning theory and the Knowledge-Based View predict that website-based ESG disclosure intensity may be associated with performance in ways that correspond to codified knowledge assets (Nonaka, 1994; Grant, 1996). This framework suggests that strategic initiatives may be associated with competitive advantage when they correspond to the organisational capability to transform activities into codified knowledge assets. However, as with the direct association between ESG and growth (H3), this association may be substantially constrained in early-stage, resource-constrained startups. H5 therefore does not test a causal mediation pathway. It tests whether a cross-sectional association between website-based ESG disclosure intensity and codified knowledge assets is observable in the sample.

In principle, startups with more intensive website-based ESG disclosure may also have more developed routines for collecting and organising sustainability-related information, which could correspond to more codified knowledge outputs (Crossan et al., 1999; Argote et al., 2020). If associated with higher levels of codified knowledge assets, website-based ESG disclosure intensity may reflect codified knowledge assets that provide competitive differentiation (Barbieri et al., 2020).

Sustainability-oriented innovation literature identifies three possible channels through which sustainability-related activity may be associated with knowledge creation: problem identification that reveals operational inefficiencies; stakeholder engagement that surfaces unmet market needs; and focused experimentation that stimulates creative problem-solving (Klewitz & Hansen, 2014; Adams et al., 2016). Green patents represent observable outcomes of technological knowledge creation motivated by environmental imperatives (Fabrizi et al., 2018; Barbieri et al., 2020), although the present study uses a broader measure of codified knowledge assets. Digital technologies may facilitate this correspondence through real-time ESG data capture and analytics (Wang et al., 2023; Fang, 2024).

However, substantial theoretical and empirical considerations suggest this association is likely to be weak or undetectable in early-stage startups. Many ventures exhibit high ESG communication scores but have limited patent portfolios, indicating that ESG disclosure does not automatically correspond to higher levels of codified knowledge assets (Berg et al., 2022; Mansouri & Momtaz, 2022). Knowledge creation requires absorptive capacity-i.e., prior related knowledge and organisational learning routines (Cohen & Levinthal, 1990). Resource-constrained startups often lack sufficient R&D infrastructure to convert ESG-related insights into patentable innovations (Zahra et al., 2006).

The strength of any such association depends critically on sectoral innovation intensity and knowledge management capabilities. High-innovation sectors provide institutional conditions that strengthen the association between ESG disclosure and codified knowledge assets (Malerba, 2002; Castellacci, 2008). Meta-analytic evidence confirms that absorptive capacity effects on innovation are significantly moderated by industry knowledge intensity (Stettler et al., 2025). Low-innovation sectors exhibit constrained absorptive capacity, reducing the likelihood of correspondence between ESG disclosure and codified knowledge assets. Knowledge integration capabilities determine whether strategic initiatives translate into innovation outcomes (Scaringella & Scaringella, 2025). Firms with superior knowledge management systems more effectively organise sustainability-related information in ways that may correspond to formal knowledge outputs (Di Vaio et al., 2021; He et al., 2024). However, weak knowledge integration (common in resource-constrained startups) prevents this correspondence, leaving ESG disclosure as predominantly a legitimacy signal (Riaz et al., 2024).

H5 examines whether the data provide evidence of the ESG disclosure-codified knowledge asset association that would be expected if the proposed knowledge-related pathway were present. Given resource constraints, shallow ESG institutionalisation, and the weak absorptive capacity typical of early-stage ventures, we expect any cross-sectional association between website-based ESG disclosure intensity and codified knowledge assets at baseline to be weak or undetectable. Accordingly, **H5:** Website-based ESG disclosure intensity is not significantly associated with codified knowledge assets at baseline.

Conceptual model and synthesis

The theoretical framework integrates five hypotheses, specifying how industry context, codified knowledge assets, and ESG disclosure are expected to be associated with startup growth trajectories. The conceptual model positions industry context as the primary sector-level condition, creating divergent growth conditions (Castellacci, 2008; Hillman et al., 2009). Under these conditions, codified knowledge assets are expected to be the focal firm-level predictor of growth, thereby conferring competitive advantage through technological differentiation and signalling quality (Griliches, 1990; Connelly et al., 2011). Website-based ESG disclosure intensity is theorised as a conditional, potentially limited short-term signal, the relevance of which depends critically on industry context and knowledge-creation capacity.

In industries where stakeholders place high priority on visible sustainability-related signals, ESG disclosures could serve as legitimacy signals that facilitate access to resources (Mitchell et al., 1997; Bridoux & Stoelhorst, 2022). In sectors that prioritise technical performance over sustainability credentials, theoretical expectations suggest that associations with ESG disclosure will remain weak or absent (Aragon-Correa & Sharma, 2003). If ESG disclosure is associated with growth, this would theoretically require at least an observable association between website-based ESG disclosure intensity and codified knowledge assets, particularly in ventures operating in high-innovation-intensity sectors (Barbieri et al., 2020; Stettler et al., 2025). However, as developed in Sections 2.3 and 2.5, multiple theoretical constraints suggest these mechanisms are substantially constrained in early-stage, resource-constrained ventures.

This multi-level model reflects three interconnected theoretical dynamics. First, industry context shapes sectoral innovation norms, determining which innovation mechanisms are expected to dominate (Malerba, 2002). Second, knowledge management effectiveness depends on absorptive capacity, with codified knowledge assets potentially serving as an associated firm-level condition (Cohen & Levinthal, 1990; Grant, 1996). Third, website-based ESG disclosure associations must be understood within realistic boundary conditions, with theoretical frameworks specifying where, when, and how ESG disclosure may influence startup performance (Mansouri & Momtaz, 2022).

The framework positions startups within nested institutional contexts: industry structures create opportunity sets (Pfeffer & Salancik, 1978), sectoral innovation systems condition knowledge-creation capabilities (Castellacci, 2008), and institutional environments determine stakeholder salience configurations (DiMaggio & Powell, 1983). These theoretical arguments motivate testable hypotheses about the relative importance of structural, knowledge-based, and website-based ESG disclosure associations in shaping early-stage venture performance.

Data, variables, and empirical strategy

Research setting and data integration

This study examines a selected sample of early-stage European

digitalised startups, observed through archived website traces, ORBIS-linked financial and employment records, and observable, codified knowledge-asset data over the 2019–2024 period. The term 'digital startup' refers to ventures with identifiable digital components in their products, services, distribution channels, or publicly articulated market positioning. The study therefore does not treat digitality as equivalent to high technological intensity; rather, it requires sufficient public website observability to measure baseline disclosure consistently.

The empirical design uses a two-tier structure. Tier 1 is the broader ORBIS-observable startup population. Tier 2 is the reduced analytical sample for which archived website text, website-based ESG disclosure intensity, codified knowledge assets, mapped sector-level contextual variables, and growth outcomes are all observable. The regression analyses are estimated only on Tier 2; Tier 1 is used solely to assess selection into the analytical sample.

Data were assembled primarily from ORBIS, which provides harmonised financial and employment information for European private and public firms. ORBIS does not classify firms as startups; therefore, startup status was established using European definitional criteria-namely, legal independence, age of <10 years at the start of the observation period, and evidence of early-stage commercial activity. ORBIS further supplies legal industry codes based on NACE; the first digit of each firm's primary NACE code is mapped to the closest available OECD-recognised sector category used to construct sector-level contextual variables.

Tier 1 data are used for descriptive comparison and selection diagnostics. The Tier 1 frame comprises all firms that meet the startup criteria and for which ORBIS reports non-estimated multi-year financial and employment data. From this frame, 2465 startups remain after deduplication across firms originating within and outside the EU Startup Database's reference set.

Tier 2 is derived from this frame and comprises firms for which additional website disclosures and codified knowledge-asset information can be systematically observed. Among the 2465 firms, 567 had archived website snapshots accessible for the baseline year. Of these, 312 maintained a consistent website identity without rebranding or domain migration that would impede text comparability. After excluding firms whose archived website content consists mainly of placeholders or non-substantive material, 260 remained with usable textual disclosures. Industry classification requires a clear, one-to-one mapping to legally recognised OECD industry categories; firms lacking such an unambiguous assignment were excluded, reducing the sample to 209. Among these, only 175 exhibited any detectable sustainability-related terminology in their baseline-year website text. Finally, ensuring that each firm had complete observations across revenue growth, employment growth, codified knowledge assets, website-based ESG disclosure intensity, and sectoral innovation intensity yielded a fully consistent analytical dataset of 144 startups. This sequential reduction reflects the observability requirements of the empirical design: stable archived websites, usable baseline text, unambiguous industry mapping, detectable sustainability-related terminology, and complete linked firm-level data. Table 1 traces the cumulative filtering steps from the Tier 1 frame to the final analytical sample.

Table 1
Sample construction process.

Stage	N
Tier 1: ORBIS-observable startups with non-estimated multi-year data	2465
Archived website snapshots accessible at baseline year	567
Consistent website identity (no rebranding/domain migration)	312
Usable textual disclosures (excluding placeholders)	260
Unambiguous single-industry classification	209
Detectable sustainability-related terminology at baseline	175
Complete data on growth, codified knowledge assets, website-based ESG disclosure intensity, and sectoral innovation intensity	144

Note: Each row reflects a cumulative filter applied to the preceding stage.

Because the analytical sample requires detectable sustainability-related terminology at baseline, the regression results should be interpreted as variation in website-based ESG disclosure intensity among startups with at least some observable sustainability-related language on their websites, rather than as a comparison between startups with and without any ESG disclosure.

To assess selection into the analytical sample based on observable characteristics, inverse-probability weights were estimated using Tier 1 ORBIS-observable variables. This exercise was used diagnostically rather than correctively. Because the estimated propensity scores indicated weak overlap between the analytical sample and the broader ORBIS-observable frame, the weighted models were not used for population-level inference. Instead, the IPW exercise informed the external-validity boundary of the study.

The analytical sample should therefore be interpreted as a selected subset of startups with stable observable disclosure footprints and complete linked data, not as a representative sample of early-stage European digital startups in general.

Temporal structure and growth measurement

All focal explanatory variables were measured at baseline year t, defined relative to each firm's most recent available outcome year in the observation window. The outcome year, denoted t + 5, contains the latest available revenue and employment information used to compute five-year growth. For each firm, annual values in years t + 1 through t + 4 formed the intermediate observations. This structure yielded a five-year performance window while maintaining consistent temporal separation between focal predictors and growth outcomes. Firm-size controls were measured using the first available post-baseline observations at t + 1 rather than the same baseline values used to calculate growth rates, thereby reducing mechanical overlap with the outcome measures.

The models therefore relate baseline website-based ESG disclosure intensity, codified knowledge assets, and sector-level context to subsequent five-year growth, while controlling for early observed firm scale. Depending on the availability of firm-level data, the calendar years underlying t and t + 5 vary across firms. Although intermediate annual observations were available, the main empirical models were estimated cross-sectionally, relating baseline characteristics to subsequent multi-year growth outcomes.

Firm-level performance was captured using five-year Average Annual Growth in Revenue (AAGR) and Average Annual Growth in Employment (AAGE), computed directly from ORBIS financial and headcount data as the arithmetic mean of the five annual growth rates observed between t and t + 5:

$$AAGE_i = (1/5)\cdot(s = 1to5)\left[\left(E_{i,t+s} - E_{i,t+s-}\right) / E_{i,t+s-1}\right]$$

$$AAGE_i = (1/5)\cdot(s = 1to5)\left[\left(E_{i,t+s} - E_{i,t+s-}\right) / E_{i,t+s-1}\right]$$

where R denotes firm revenue (in PPP-adjusted USD), and E denotes firm headcount, both observed in ORBIS for firm i in year t+s. These measures capture average annual changes over the five-year observation window rather than year-by-year panel effects. Because startup growth distributions are highly skewed and include negative and extreme positive values, the main regressions use inverse hyperbolic sine transformations of AAGR and AAGE. Raw and 2.5% winsorised values are retained for descriptive and supplementary checks, but substantive inference is based on the asinh-transformed outcomes.

Website-based ESG disclosure intensity

Website-based ESG disclosure intensity was constructed from the textual content of firms' websites at baseline year t. Archived snapshots were retrieved from the Internet Archive's Wayback Machine, and public website text was cleaned to remove boilerplate and irrelevant

elements. The measure was quantified using dictionary-based content analysis, following the logic of structured lexical mapping approaches, such as those of Mansouri and Momtaz (2022).

Following this approach, each firm's cleaned website text was analysed for the presence and relative weight of terminology associated with the environmental, social, and governance dimensions of sustainability, as defined in the ESG lexicon used in the dictionary-based coding procedure. Environmental terms relate to ecological impact, energy use, climate, or resource considerations; social terms relate to labour, diversity, community, or well-being themes; and governance terms relate to responsibility, transparency, compliance, and internal control. Term frequencies were normalised by corpus length to produce a continuous measure of website-based ESG disclosure intensity. The resulting variable was interpreted strictly as website-based ESG disclosure intensity: it captures the relative salience of sustainability-related terminology in archived website text, not ESG engagement, sustainability orientation, stakeholder pressure, implementation quality, or verified ESG performance.

Codified knowledge assets

The empirical framework captured observable formal knowledge outputs through a composite measure of codified knowledge assets at baseline. These assets include: (i) patent applications filed with the World Intellectual Property Organization (WIPO), the European Patent Office (EPO), or national patent authorities; (ii) registered unique trademarks or copyrights relevant to operational or technological aspects of the business model, excluding purely brand-only marks where applicable; and (iii) academic publications authored by founders or employees and directly affiliated with the firm's technological or operational activities, as indicated on the firm's website or its linked digital profiles.

These elements collectively represent observable formal knowledge outputs and codification activity. For modelling purposes, these assets were aggregated into a total count. To account for the highly skewed distribution and prevalence of zero-valued observations (11.1% of firms had no codified knowledge assets and 50.7% of firms held no patents), the regression variable was derived from the log transformation (log(1 + total codified knowledge asset count)) and subsequently standardised (z-score). While this composite measure captures formalised knowledge outputs, informal or tacit knowledge creation remains largely unobservable in early-stage firms, so the measure should be interpreted as a conservative proxy for observable formal knowledge outputs rather than for total firm-level knowledge capital. Because the regression variable aggregates patents with non-patent codified outputs, results are interpreted as associations with codified knowledge assets as a composite measure, not as evidence of technological knowledge quality.

Industry assignment and contextual variables

Industry assignment was based on each firm's legally registered primary NACE industry code in ORBIS, mapped at the one-digit level to the closest available OECD STAN sector category used for the sector-level contextual variables. Because OECD STAN sector categories do not always align neatly with one-digit NACE groupings, this mapping should be interpreted as a coarse-grained sectoral assignment rather than a precise industry identification. These sector-level variables collectively operationalise the overarching theoretical construct of 'industry context', capturing distinct dimensions of sectoral growth conditions and knowledge regimes. OECD sector-level data were used to construct contextual measures of sector-level growth and innovation intensity; monetary indicators are expressed in PPP-adjusted U.S. dollars where applicable. For regression modelling, the mapped industry-level measures were standardised as z-scores within the analytical sample.

Two sector-level contextual variables were constructed from the OECD industry categories, each capturing a different facet of industry context. First, the OECD-derived sector-level growth proxy captures sectoral value-added growth from the OECD STAN database over the five-year window aligned with the firm-level observation period. This variable was assigned to firms based on their OECD industry category and standardised within the analytical sample; it is external to the firm-level growth outcomes and should not be interpreted as a direct measure of each firm's market conditions. Second, sectoral innovation intensity is based on sectoral R&D intensity (average R&D spending per company) for the OECD industry category; it should be interpreted as a sectoral knowledge-regime proxy, distinct from the growth proxy, and not as a direct measure of stakeholder sustainability scrutiny, consumer visibility, institutional pressure, or legitimacy demand. Because the sectoral R&D intensity measure is right-skewed, it was log-transformed before standardisation. Together, these contextual variables situate firms within broader sectoral environments, but they do not fully capture industry structure, firm-level opportunity conditions, or causal sectoral effects.

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These contextual variables situate firms within broader sectoral environments. They do not fully capture industry structure, firm-level opportunity conditions, or causal sectoral effects.

Empirical strategy

The empirical analysis applied ordinary least squares regression models to the selected sample of 144 firms. For the auxiliary cross-sectional association test in which the dependent variable is a count of codified knowledge assets, negative binomial regression was used to account for overdispersion. To improve comparability across focal predictors, website-based ESG disclosure intensity, log-codified knowledge assets, sectoral innovation intensity, and the OECD-derived sector-level growth proxy were standardised as z-scores prior to model estimation. All focal variables are anchored at or derived from baseline year t. The resulting coefficients should be interpreted as conditional associations rather than causal effects; temporal separation reduces, but does not eliminate, concerns related to endogeneity and reverse causality.

The modelling strategy examines the associations between each predictor and firm-level growth while maintaining temporal separation between the measurement of predictors and outcomes. Interaction terms were incorporated where specified by the hypotheses, and the website-based ESG disclosure intensity-codified knowledge asset association was tested separately as an auxiliary cross-sectional association test. Additional diagnostics included variance inflation factors to assess multicollinearity and transformed or winsorised growth measures to reduce the influence of skewness and extreme values. The nested OLS tables report conventional standard errors to preserve comparability across the sequential specifications. Because heteroskedasticity diagnostics rejected homoskedasticity across specifications, substantive inference was evaluated using HC3 heteroskedasticity-consistent standard errors, as reported in Table 8.

With a selected analytical sample of N = 144, the study is powered to detect medium-to-large standardised associations, while the interpretation of near-zero coefficients-particularly for interaction terms-is treated with appropriate caution. These constraints, together with the observational design, two-tier sample structure, and limited disclosure environment characteristic of early-stage ventures, mean that the methodological aim was to provide a transparent and replicable account of how website-based ESG disclosure intensity, codified knowledge assets, and sector-level context relate to five-year revenue and employment growth given the data constraints inherent in the European startup

landscape.

The empirical strategy is therefore designed to estimate conditional associations within the selected analytical sample. It does not identify causal effects, validate temporal mechanisms, or support mechanical generalisation to the broader population of early-stage European digital startups.

Results

This section reports descriptive evidence, nested regression results, the cross-sectional website-based ESG disclosure intensity-codified knowledge asset association test, and robustness checks. The objective is to evaluate whether website-based ESG disclosure intensity is associated with five-year revenue and employment growth in the selected analytical sample once baseline characteristics, an OECD-derived sector-level growth proxy, sectoral innovation intensity, and codified knowledge assets are accounted for.

All continuous focal predictors -website-based ESG disclosure intensity, log-codified knowledge assets, the OECD-derived sector-level growth proxy, and sectoral innovation intensity- were standardised as z-scores. Baseline controls (age, log revenue, log headcount) were entered into the models in their original metrics. Coefficients for standardised focal predictors represent the association of a one-standard-deviation increase with the asinh-transformed growth outcome, enabling direct comparison across standardised focal predictors. Substantive inference is based on the asinh-transformed outcomes; raw and 2.5% winsorised values are reported descriptively. IPW diagnostic results are summarised in Appendix B and are not used for inference due to the weak propensity-score overlap. The estimates are interpreted associationally; no causal claims are made.

Sample construction, selection diagnostics, and statistical power

The analytical sample comprises 144 early-stage European digitalised startups drawn from a Tier 1 sampling frame of 2465 firms. Sample inclusion required a stable archived digital presence at baseline, identifiable sustainability-related terminology, unambiguous industry classification, and complete data across growth, codified knowledge assets, and website-based ESG disclosure intensity variables. These conditions produce systematic differences relative to the Tier 1 frame, particularly in baseline revenue.

Included firms are younger on average (5.88 versus 6.20 years), report higher mean log baseline revenue (12.15 versus 7.94 in log PPP USD), and have comparable log baseline headcounts (2.52 in both samples). The largest selection differential is in financial size: sample firms are more likely to have observable financial information. Country and industry composition could not be incorporated into selection modelling because industry classification was ambiguous or estimated for more than ~20% of Tier 1 firms, while country assignment was also unstable for a substantial share of firms due to headquarters changes during the observation window. The analytical sample is therefore conditioned on archival observability, disclosure stability, and complete linked data; it should not be interpreted as representative of the broader startup population.

Inverse-probability weights were estimated by modelling analytical-sample inclusion as a function of age, log baseline revenue, and log baseline headcount. The estimated propensity scores are severely skewed, with a median of approximately 0.006, and the maximum trimmed weight exceeds 237. Residual imbalance on baseline revenue remains substantial after reweighting (SMD = 0.54). This weak overlap is itself informative: it indicates that the analytical sample occupies a distinctive region of the broader ORBIS-observable startup distribution. IPW results are therefore reported only as diagnostics of sample distinctiveness and are not used for inference.

With N = 144 and eight predictors in the full specification, the study is best powered to detect medium-to-large standardised associations. The codified-knowledge coefficient for revenue growth is within the range the study is better positioned to detect. In contrast, the employment-growth coefficient is smaller but remains statistically distinguishable from zero in the observed specification. By contrast, the website-based ESG disclosure intensity coefficients remain consistently close to zero across specifications. The main power constraint, therefore, concerns the interaction tests, as small conditional associations would require substantially larger sample sizes to detect reliably.

Descriptive statistics and variable distributions

Growth outcomes are right-skewed (Table 2). Revenue growth ranges from −37.4% to 2424.5% (SD = 363.6%); employment growth from −50.0% to 650.0% (SD = 101.0%). These distributions motivate the use of the inverse hyperbolic sine (asinh) transformation, which compresses extreme tails while preserving zero and negative values. Because the outcomes include negative and extreme positive values, coefficients are interpreted primarily in terms of direction, relative magnitude, and model fit. Multicollinearity diagnostics indicate no evidence of problematic collinearity; all VIFs are below 1.73, with the maximum observed for log baseline headcount.

Website-based ESG disclosure intensity is a dictionary-based score derived from archived baseline-year website text that captures the relative salience of environmental, social, and governance terminology. This measure captures disclosure salience, not externally verified sustainability outcomes. Codified knowledge assets are the log-transformed count of patents, trademarks, copyrights, and publications observable at baseline. Table 3 reports the component-level composition: 330 patents and 488 other codified knowledge assets, for a total of 818. Zero-valued observations are common: 50.7% of firms hold zero patents; 12.5% hold zero non-patent codified assets; 11.1% hold zero total codified knowledge assets. Patent-only regressions are not used as main specifications because of the high prevalence of zero patent counts and the limited stability this would induce in the analytical sample. Industry-level descriptive statistics for the analytical sample are reported in Appendix A. The OECD-derived sector-level growth proxy is an external

Table 2
Descriptive statistics (N = 144).

Variable	Min	Max	Median	Mean	SD
AAGR (%)	−37.39	2424.48	44.76	169.51	363.6
AAGE (%)	−50.00	650.00	16.67	51.81	101.0
asinh(AAGR)	−0.37	8.49	0.44	1.31	1.44
asinh(AAGE)	−0.48	7.17	0.17	0.43	0.52
Age (years)	2.0	13.0	6.0	5.88	2.52
Log baseline revenue (PPP USD)	2.48	17.61	12.67	12.15	3.16
Log baseline headcount	0.69	6.12	2.40	2.52	1.32
Website-based ESG disclosure intensity (z-score)	−1.44	3.73	−0.16	0.00	1.00
Log codified knowledge assets (z-score)	−1.95	1.80	0.22	0.00	1.00
OECD-derived sector-level growth proxy (z-score)	−1.69	1.56	0.02	0.00	1.00
Log sectoral innovation intensity (z-score)	−2.32	1.37	0.59	0.00	1.00

Notes: Raw growth rates are shown for AAGR and AAGE; asinh-transformed values are used in the regression models. Standardised focal predictors (website-based ESG disclosure intensity, log-codified knowledge assets, OECD-derived sector-level growth proxy, and sectoral innovation intensity) have a mean of 0 and an SD of 1 by construction. Baseline controls (age, log baseline revenue, log baseline headcount) were entered in their original metrics. Log codified knowledge assets = log(1 + total codified knowledge asset count), subsequently standardised. Shortened labels are used only where needed for table readability; all references denote website-based ESG disclosure intensity and log-codified knowledge assets as defined above. Extended descriptive statistics and diagnostics are reported in Supplementary File S1.

Table 3
Codified knowledge asset composition (N = 144).

Component	Firms ≥ 1	Firms = 0	% zero	Total count	Mean (raw)	SD (raw)
Patents	71	73	50.7%	330	2.29	3.41
Other codified knowledge assets (trademarks, copyrights, publications)	126	18	12.5%	488	3.39	4.87
Total codified knowledge assets	128	16	11.1%	818	5.68	-

Notes: Raw (unstandardised) counts. The regression variable, log-codified knowledge assets (z-score), is derived from log(1 + total codified knowledge asset count) and standardised. Patent-only regressions are not used as the main specifications because 50.7% of firms hold zero patents, which reduces the statistical power and stability of the analytical sample. Extended tables and data are reported in Supplementary File S1.

sectoral indicator mapped to each firm's OECD first-digit industry classification; it is external to the firm-level growth outcomes in the analytical sample and avoids mechanical overlap within the sample. Log sectoral innovation intensity is derived from the same OECD mapping and is interpreted as a sectoral knowledge-regime proxy based on R&D intensity.

Revenue growth results (AAGR)

Table 4 reports nested OLS regressions for five-year revenue growth. Specifications R1-R6 sequentially add predictors, progressing from baseline controls to the full interaction model.

Control Variables. R1 explains 14.6% of variance. Log baseline revenue is negative and significant across all specifications (b = −0.073, SE = 0.024, p = .002), consistent with baseline-size scaling and possible regression-to-the-mean dynamics. Age enters negatively and significantly from R3 onward (b = −0.077, SE = 0.030, p = .011). Log baseline headcount is not significant.

Industry. The OECD-derived sector-level growth proxy does not improve model fit (R2: b = −0.015, SE = 0.071, p = .829; $\Delta R^2 = 0.000$). Because this measure is constructed from OECD data external to the analytical sample, it avoids within-sample mechanical overlap. The OECD-derived sector-level growth proxy is not significantly associated with firm-level revenue growth in these specifications.

Codified knowledge assets produce the largest increment in explanatory power in the revenue models (R3: $\Delta R^2 = +0.205$, from 0.146 to 0.351). The coefficient is positive and significant (b = 0.406, SE = 0.062, $p < .001$). A one-standard-deviation increase in log-codified knowledge assets corresponds to a 0.41-unit increase in asinh(AAGR), substantially larger than the website-based ESG disclosure intensity coefficient in any specification. The association remains stable across R4-R6 (b = 0.398–0.406, all $p < .001$).

Website-based ESG disclosure intensity is not statistically significant in any revenue specification (R4-R6: |b| < 0.012, all $p > .85$; $\Delta R^2 = 0.000$). Its inclusion does not alter the magnitude or significance of other predictors. The point estimates are close to zero.

The website-based ESG disclosure intensity × sectoral innovation intensity interaction is not significant for revenue growth (R6: b = −0.051, SE = 0.072, p = .480; $\Delta R^2 = +0.003$).

Employment growth results (AAGE)

Table 5 reports the parallel nested specifications for employment growth. All continuous focal predictors are standardised.

Control Variables. E1 explains 21.5% of variance. Log baseline headcount is negative and significant in every specification (b = −0.175, SE = 0.038, $p < .001$), consistent with baseline-size scaling in employment growth rates. This parallels the role of log baseline revenue in AAGR. Age is not a significant factor in employment growth.

Industry. The OECD-derived sector-level growth proxy is marginally significant in E2 (b = 0.073, SE = 0.039, p = .065; $\Delta R^2 = +0.019$) and becomes significant once codified knowledge assets are controlled for (E3-E6: b = 0.074–0.083, p = .038-.047). This contrasts with the revenue results, where the OECD-derived sector-level growth proxy was not significant in any specification. The OECD-derived sector-level growth proxy is positively associated with employment growth but not revenue growth in this selected sample. Because the measure is an external sector-level proxy, this result should be interpreted as evidence of an employment-growth association with mapped sectoral growth conditions, not as evidence that the variable fully captures each startup's specific market opportunity.

Knowledge assets. Log codified knowledge assets again produce the largest incremental R^2 (E3: $\Delta R^2 = +0.118$, from 0.234 to 0.352). The coefficient is positive and significant (b = 0.179, SE = 0.036, $p < .001$), and stable across E4-E6. The AAGE coefficient (0.18) is smaller than the AAGR coefficient (0.41), indicating that the estimated association between codified knowledge assets and growth is larger for revenue growth than for employment growth in these specifications.

Website-based ESG disclosure intensity is not significant in any employment specification (E4-E6: |b| < 0.020, all $p > .64$). Sectoral

Table 4
Nested OLS regressions: asinh-transformed revenue growth, N = 144.

Dependent variable: asinh(AAGR)	R1	R2	R3	R4	R5	R6
Age	−0.0531 (0.0336)	−0.0537 (0.0338)	−0.0768* (0.0298)	−0.0771* (0.0302)	−0.0749* (0.0299)	−0.0769* (0.0304)
Log baseline revenue	−0.0726** (0.0235)	−0.0728** (0.0236)	−0.0698** (0.0207)	−0.0700** (0.0209)	−0.0687** (0.0207)	−0.0701** (0.0208)
Log baseline headcount	−0.0683 (0.0678)	−0.0692 (0.0682)	−0.0289 (0.0600)	−0.0281 (0.0610)	−0.0322 (0.0604)	−0.0294 (0.0607)
OECD-derived sector-level growth proxy (z)	-	−0.0154 (0.0708)	−0.0113 (0.0619)	−0.0120 (0.0629)	−0.0634 (0.0677)	−0.0564 (0.0684)
Log codified knowledge assets (z)	-	-	0.4061*** (0.0616)	0.4064*** (0.0620)	0.3980*** (0.0615)	0.3984*** (0.0617)
Website-based ESG disclosure intensity (z)	-	-	-	−0.0046 (0.0632)	−0.0017 (0.0625)	−0.0120 (0.0643)
Log sectoral innovation intensity (z)	-	-	-	-	0.1290† (0.0665)	0.1219† (0.0674)
Website-based ESG disclosure × sectoral innovation	-	-	-	-	-	−0.0509 (0.0718)
R^2	0.146	0.146	0.351	0.351	0.368	0.371
Adj. R^2	0.128	0.122	0.327	0.322	0.336	0.333
ΔR^2	-	+0.000	+0.205	+0.000	+0.017	+0.003
Observations	144	144	144	144	144	144

Notes: † $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$. Conventional OLS standard errors are reported for comparability with the nested model sequence. Because heteroskedasticity diagnostics reject homoskedasticity, substantive inference is evaluated using HC3 heteroskedasticity-consistent standard errors reported in Table 8. Intercept estimated but not shown. Full robustness output is retained in Supplementary File S1.

Table 5
Nested OLS regressions: asinh-transformed employment growth, N = 144.

Dependent variable: asinh(AAGE)	E1	E2	E3	E4	E5	E6
Age	−0.0137 (0.0187)	−0.0110 (0.0186)	−0.0213 (0.0173)	−0.0206 (0.0175)	−0.0209 (0.0175)	−0.0202 (0.0177)
Log baseline revenue	0.0145 (0.0131)	0.0157 (0.0130)	0.0170 (0.0120)	0.0174 (0.0121)	0.0173 (0.0121)	0.0178 (0.0122)
Log baseline headcount	−0.1746*** (0.0377)	−0.1703*** (0.0375)	−0.1525*** (0.0348)	−0.1542*** (0.0354)	−0.1536*** (0.0355)	−0.1547*** (0.0357)
OECD-derived sector-level growth proxy (z)	-	0.0725† (0.0389)	0.0743* (0.0359)	0.0759* (0.0365)	0.0833* (0.0398)	0.0806* (0.0403)
Log codified knowledge assets (z)	-	-	0.1789*** (0.0357)	0.1780*** (0.0359)	0.1793*** (0.0361)	0.1791*** (0.0362)
Website-based ESG disclosure intensity (z)	-	-	-	0.0107 (0.0366)	0.0103 (0.0367)	0.0143 (0.0378)
Log sectoral innovation intensity (z)	-	-	-	-	−0.0186 (0.0391)	−0.0159 (0.0396)
Website-based ESG disclosure × sectoral innovation	-	-	-	-	-	0.0196 (0.0422)
R^2	0.215	0.234	0.352	0.352	0.353	0.354
Adj. R^2	0.198	0.212	0.328	0.324	0.320	0.316
ΔR^2	-	+0.019	+0.118	+0.000	+0.001	+0.001
Observations	144	144	144	144	144	144

Notes: † $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$. Conventional OLS standard errors are reported for comparability with the nested model sequence. Because heteroskedasticity diagnostics reject homoskedasticity, substantive inference is evaluated using HC3 heteroskedasticity-consistent standard errors reported in Table 8. Intercept estimated but not shown. Full robustness results are reported in Supplementary File S1.

innovation intensity and the website-based ESG disclosure intensity × sectoral innovation intensity interaction are also not significant. The point estimates are small and not distinguishable from zero.

Across both outcomes, the interaction between website-based ESG disclosure intensity and sectoral innovation intensity is not significant. Conditional slopes of website-based ESG disclosure intensity remain small and statistically indistinguishable from zero at low, mean, and high levels of sectoral innovation intensity. Because sectoral innovation intensity is a sectoral knowledge-regime proxy rather than a direct measure of stakeholder sustainability scrutiny, this interaction should be interpreted as a limited contextual probe rather than a direct test of stakeholder pressure.

Website-based ESG disclosure intensity-codified knowledge asset association

H5 examines whether website-based ESG disclosure intensity is cross-sectionally associated with codified knowledge assets at baseline. Because both variables are measured contemporaneously, this test does not evaluate mediation, sequencing, or a temporal learning-to-codification pathway. Instead, it assesses whether the two baseline measures covary in a direction consistent with the proposed association.

Because codified knowledge asset counts exhibit overdispersion, a negative binomial regression with a log link was used, consistent with standard count-modelling practice. Website-based ESG disclosure intensity is not significantly associated with raw codified knowledge asset count (b = 0.094, SE = 0.073, $p = .197$; Table 7). The dispersion parameter ($\alpha = 0.583$, $p < .001$) confirms that a negative binomial is appropriate; a Poisson specification would be less appropriate under this overdispersion. Pearson goodness-of-fit (χ^2 $p = .816$) indicates adequate model fit. The H5 association test therefore yields a null result, and H5 is not supported.

Robustness and supplementary checks

Breusch-Pagan and White-type tests reject homoskedasticity in all twelve specifications (all $p < .001$; Appendix C), motivating HC3 standard errors for substantive inference. HC3 is commonly recommended for smaller samples because of its finite-sample properties. Table 8 compares inference for focal predictors in R6/E6. Log-codified knowledge assets remain significant for both outcomes ($p < .001$ under HC3). The OECD-derived sector-level growth proxy remains significant for employment (HC3 $p = .044$) but not revenue (HC3 $p = .422$). Website-based ESG disclosure intensity remains non-significant for either outcome (HC3 $p = .872$ for AAGR; $p = .696$ for AAGE). The only substantive change in inference is that log sectoral innovation intensity in AAGR moves from marginal to non-significant under HC3 ($p = .117$). Interaction terms remain non-significant.

IPW diagnostics (summarised in Appendix B) indicate weak overlap, extreme leverage, residual imbalance, and unstable weighted-model behaviour. The weighted results are therefore not used for inference. Instead, the IPW exercise reinforces the study's external-validity boundary: the analytical sample is a distinctive, disclosure-observable subset of the broader ORBIS startup sampling frame.

Summary of results

Table 9.

Codified knowledge assets make the largest incremental explanatory contribution among the sequentially added focal predictors for both revenue growth ($\Delta R^2 = 0.205$) and employment growth ($\Delta R^2 = 0.118$). The OECD-derived sector-level growth proxy is positively associated with employment growth but not revenue growth. Website-based ESG disclosure intensity is not significantly associated with either outcome, and its coefficients remain close to zero across specifications. The website-based ESG disclosure intensity × sectoral innovation intensity interaction is not significant for either outcome, and the interaction signs differ across outcomes (Table 6). The cross-sectional baseline association between website-based ESG disclosure intensity and codified knowledge assets is also null in the negative binomial model. HC3-based inference does not alter the main conclusions. The IPW diagnostic

Table 6
Conditional slopes of website-based ESG disclosure intensity at different levels of sectoral innovation intensity.

Outcome	Sectoral innovation level	Conditional slope	Interaction b	Interaction p
AAGR	Low (−1 SD)	+0.039	−0.051	.480
AAGR	Mean (0)	−0.012	−0.051	.480
AAGR	High (+1 SD)	−0.063	−0.051	.480
AAGE	Low (−1 SD)	−0.005	+0.020	.643
AAGE	Mean (0)	+0.014	+0.020	.643
AAGE	High (+1 SD)	+0.034	+0.020	.643

Notes: Conditional slopes computed as b_ESG + b_interaction × sectoral innovation level. None of the slopes is statistically distinguishable from zero. Interaction signs are opposite across outcomes (AAGR: negative; AAGE: positive); neither is significant. Extended tables and data are reported in Supplementary File S1.

Table 7
Cross-sectional baseline association between website-based ESG disclosure intensity and raw codified knowledge asset count.

Specification	b	SE	p	95% CI	Dispersion α	N
Negative binomial (controls)	0.094	0.073	.197	[−0.049, 0.238]	0.583	144

Notes: Dependent variable = raw codified knowledge asset count. Negative binomial with log link. Controls: age, log revenue, log headcount. $\alpha = 0.583$ ($p < .001$) confirms overdispersion. Pearson χ^2 $p = .816$. Extended tables and data are reported in Supplementary File S1.

Table 8
HC3 robustness checks for focal predictors in the full specifications (R6 and E6).

Outcome / Predictor	OLS b	OLS p	HC3 SE	HC3 *p*	SE change	Inference
AAGR (R6)						
Log codified knowledge assets	0.398	<.001	0.067	<.001	+8%	Unchanged
Website-based ESG disclosure intensity	−0.012	.852	0.074	.872	+16%	Unchanged
OECD-derived sector-level growth proxy	−0.056	.412	0.070	.422	+2%	Unchanged
Log sectoral innovation intensity	0.122	.073	0.077	.117	+15%	† → ns
Website-based ESG disclosure intensity × sectoral innovation	−0.051	.480	0.087	.560	+22%	Unchanged
AAGE (E6)						
Log codified knowledge assets	0.179	<.001	0.033	<.001	−8%	Unchanged
Website-based ESG disclosure intensity	0.014	.707	0.036	.696	−3%	Unchanged
OECD-derived sector-level growth proxy	0.081	.047	0.040	.044	−2%	Unchanged
Log sectoral innovation intensity	−0.016	.689	0.044	.720	+12%	Unchanged
Website-based ESG disclosure intensity × sectoral innovation	0.020	.643	0.038	.609	−9%	Unchanged

Notes: HC3 reports heteroskedasticity-consistent standard errors (MacKinnon & White, 1985) for the same point estimates reported in the full OLS specifications. The table compares inference for focal predictors only. Full HC3 model output is retained in Supplementary File S1; Appendix C reports heteroskedasticity diagnostics. Breusch-Pagan tests reject homoskedasticity across the reported specifications.

exercise summarised in Appendix B is not used for inference, but it reinforces the need to interpret the main findings as conditional on the selected analytical sample.

Although statistical power limits the detection of small standardised associations, the website-based ESG disclosure intensity coefficients are consistently close to zero across specifications. The results therefore suggest that any short-term association between website-based ESG disclosure intensity and subsequent growth, if present, is small within this observational window. These findings apply to the selected analytical sample: early-stage European digital startups with stable archived website footprints, detectable sustainability-related terminology, observable codified knowledge asset data, mapped sector-level context, and complete linked ORBIS records.

Table 9
Summary of hypotheses tests.

H	Tested association	AAGR	AAGE	Empirical support
H1	OECD-derived sector-level growth proxy and firm growth	Not supported	Supported ($p < .05$)	Positive association detected for AAGE only
H2	Codified knowledge assets and firm growth	Supported ($p < .001$)	Supported ($p < .001$)	Positive association detected for both outcomes
H3	Website-based ESG disclosure intensity and firm growth	Not supported	Not supported	No positive association detected; consistent with boundary-setting interpretation.
H4	Website-based ESG disclosure intensity × sectoral innovation intensity	Not supported	Not supported	Not supported
H5	Website-based ESG disclosure intensity and codified knowledge assets	Tested separately	Tested separately	Not supported

Notes: 'Supported' indicates a statistically significant coefficient at $p < .05$ in the hypothesised direction for the relevant test. H1 is outcome-dependent. H5 is tested separately using negative binomial regression because the dependent variable is the raw codified knowledge asset count rather than AAGR or AAGE (Table 7). Extended tables and data are reported in Supplementary File S1.

Discussion

The study examined how industry context, codified knowledge assets, and website-based ESG disclosure intensity jointly relate to revenue and employment growth in early-stage digitalised startups. Here, we summarise the main insights, interpret the weak ESG effects, discuss implications for theory and practice, and outline key boundary conditions. In line with the formal tests, codified knowledge assets are strongly associated with both revenue and employment growth; the sector-level growth proxy is associated with employment growth only; and neither the direct nor the moderated ESG associations, nor the ESG-knowledge asset association, receive empirical support in this sample.

Three main insights

A central insight is that sector-level context, as captured by external OECD indicators, is meaningfully associated with early-stage growth in our setting, particularly for employment. Startups located in industries with stronger sectoral opportunity structures-higher average growth, greater technological dynamism, more abundant capital, and supportive institutional environments-tend to have higher revenue and employment growth than comparable firms in less favourable sectors. This pattern is consistent with institutional and resource-dependence perspectives on sectoral resource configurations and institutional fields (DiMaggio & Powell, 1983; Pfeffer & Salancik, 1978; Hillman et al., 2009), and with work from sectoral innovation systems scholarship on heterogeneous technological opportunities and knowledge infrastructures (Malerba, 2002; Castellacci, 2008).

Within these sectoral opportunity structures, codified knowledge assets emerge as the primary firm-level differentiators of growth. Startups with richer portfolios of codified knowledge assets generally grow faster after accounting for industry context and baseline size. This

supports knowledge-based and resource-based views that position codified knowledge as a central strategic resource (Grant, 1996; Nonaka & Takeuchi, 1995) and highlights the dual role of patents as embodiments of technological knowledge and high-cost, credible signals in settings with pronounced information asymmetries (Griliches, 1990; Acs et al., 2002; Connelly et al., 2011). In digitalised ecosystems, where platforms magnify the visibility and scalability of intellectual property (Nambisan et al., 2019; Feroz et al., 2021), such assets appear particularly consequential for short-term performance.

A further insight concerns the role of website-based ESG disclosure intensity. As captured through website communication, this disclosure plays at most a weak short-term role in our analyses: once industry context and codified knowledge assets are controlled, its direct association with five-year growth is small and not statistically significant, and we do not detect a robust ESG-knowledge asset association or strong contextual moderation by sectoral innovation intensity. These findings are difficult to reconcile with optimistic accounts that portray ESG engagement as a straightforward engine of innovation-driven growth and instead align with more cautious evidence on the limits of ESG-performance relationships in resource-constrained, early-stage settings.

Interpreting the weak ESG effects

The limited short-term association between website-based ESG disclosure intensity and growth should not be read as evidence that ESG is irrelevant. Rather, our findings refine the conditions under which ESG-related communication can reasonably be expected to translate into performance gains in early-stage ventures.

One interpretation is that the practices reflected in website-based ESG disclosure in early-stage digital startups are often immature or weakly institutionalised. Resource-constrained ventures typically prioritise product-market fit, technological development, and survival over formal sustainability routines (Ahlstrom & Bruton, 2010; Drover et al., 2017; Zahra et al., 2006). In such contexts, ESG language on websites may not yet reflect deeply embedded practices and therefore may not generate measurable growth advantages within a five-year window.

Another interpretation concerns timing. Many theorised ESG mechanisms-such as building stakeholder trust, shaping long-term legitimacy, or accumulating learning that eventually feeds into new knowledge assets-unfold slowly (Suchman, 1995; Crossan et al., 1999; Argote & Miron-Spektor, 2011). These processes may generate benefits beyond the early growth phase or beyond the time horizon we observe. Our evidence thus speaks to the limited short-term impact of website-based ESG disclosure intensity in early-stage digitalised startups, not to the potential importance of substantive ESG practices for longer-term resilience, survival, or later-stage scaling.

Signal credibility offers a third perspective. Our measure captures ESG disclosure as website-based disclosure intensity, which is relatively low-cost and difficult to verify, whereas codified knowledge assets require substantial R&D investment and third-party examination. Signalling theory suggests that such low-cost signals are perceived as less credible, especially when symbolic adoption is possible (Spence, 1973; Connelly et al., 2011), while recent work shows that unsupported ESG communication can be detrimental although substantive signals maintain positive effects (Abraham et al., 2024). In this light, it is unsurprising that website-based ESG disclosure intensity adds little predictive power once industry context and knowledge assets are accounted for.

Taken together, these interpretations suggest that our contribution lies in specifying and documenting circumstances under which ESG disclosure does not yield strong short-term growth effects in early-stage digitalised startups.

Implications for innovation and knowledge research

Our results have several implications for innovation and knowledge research at the intersection of sustainability, digitalisation, and entrepreneurship. They first underscore the centrality of structural and knowledge-based factors in early-stage growth dynamics. The strong role of industry context is consistent with sectoral innovation systems arguments about technological opportunities, appropriability conditions, and resource flows (Malerba, 2002; Castellacci, 2008), while the finding of the importance of codified knowledge assets supports knowledge-based and resource-based perspectives that position formalised knowledge outputs as central vehicles for creating and appropriating value (Grant, 1996; Nonaka & Takeuchi, 1995).

The findings also qualify theorisation on ESG-driven innovation in startups. Much of the existing work assumes that ESG engagement naturally translates into superior innovation and performance, especially in digitalised contexts where monitoring is facilitated (Klewitz & Hansen, 2014; Adams et al., 2016; Feroz et al., 2021). Our evidence indicates that such mechanisms are contingent on the maturity and credibility of ESG practices, the firm's absorptive capacity, and the surrounding sectoral innovation regime (Cohen & Levinthal, 1990; Castellacci, 2008). In early-stage, resource-constrained ventures, the practices that website-based ESG disclosure may reflect are often not yet sufficiently embedded to produce observable growth advantages, and our disclosure-based measure may capture symbolic rather than substantive change (Di Vaio et al., 2021; Mansouri & Momtaz, 2022; Riaz et al., 2024).

A further implication concerns the ESG-knowledge-performance chain. Theoretically, substantive ESG practices, if present, could in principle trigger learning routines that culminate in codified knowledge assets (Nonaka, 1994; Grant, 1996; Argote et al., 2020). Empirically, we do not detect a strong association between website-based ESG disclosure intensity and patent or related intellectual property generation in our sample, which aligns with evidence that communication-based ESG scores often fail to predict patenting outcomes in young firms (Berg et al., 2022; Mansouri & Momtaz, 2022). This suggests that the conversion of ESG-related insights into appropriable knowledge assets is far from automatic and likely depends on organisational learning capabilities and sectoral innovation intensity (Cohen & Levinthal, 1990; Castellacci, 2008; He et al., 2024; Scaringella & Scaringella, 2025).

The results are consistent with a KBV-and-industry-context account in which sector-level conditions establish the baseline growth environment and codified knowledge assets differentiate firms within those conditions, while website-based ESG disclosure intensity operates as a conditional modifier whose short-term associations are limited in this setting (Grant, 1996; Castellacci, 2008). Signalling perspectives help explain why codified knowledge assets outperform website ESG language as growth-relevant signals under information asymmetry (Spence, 1973; Connelly et al., 2011), while stakeholder and resource-dependence views illuminate how sectoral stakeholder configurations and resource regimes shape the value attached to sustainability signals (Mitchell et al., 1997; Bridoux & Stoelhorst, 2022; Pfeffer & Salancik, 1978). Taken together, these interpretations position the contribution as primarily boundary-setting: the study clarifies where prevailing ESG-growth expectations do not hold under early-stage, disclosure-based conditions.

Implications for startups, investors, and policymakers

The findings also have implications for entrepreneurs, investors, and policymakers in sustainability-oriented, digitalised ecosystems. For startups, the results highlight the importance of industry selection and the deliberate accumulation of codified knowledge assets. The evidence is consistent with the value of sector selection: startups in sectors with more favourable growth trajectories and stronger innovation regimes are more strongly associated with growth in this sample (Castellacci, 2008; Hellemans et al., 2022). Within those sectors, building robust portfolios of codified knowledge assets is more consistently associated with short-term performance gains than relying on website-based ESG disclosure intensity as a primary lever (Drover et al., 2017; Nambisan

et al., 2019), suggesting that investors and entrepreneurs may wish to treat codified knowledge assets and sectoral context as primary indicators and website-based ESG disclosure intensity as a supplementary signal. For early-stage ventures, our findings point to the value of prioritising the development and codification of core technological capabilities, while approaching website-based ESG communication as a complementary rather than a primary short-term growth lever.

This does not imply that startups should neglect ESG. Instead, substantive ESG practices -beyond website disclosure alone- may be most effective when integrated into product design and organisational routines in ways that, over time, generate new knowledge assets such as environmentally oriented patents or sustainability-related process innovations (Fabrizi et al., 2018; Barbieri et al., 2020). ESG disclosure then becomes one element in a broader capability set, rather than a substitute for core technological and knowledge investments.

For investors, the results suggest prioritising sectoral opportunity and codified knowledge assets as primary screening criteria, and using ESG website disclosures mainly as a weak, complementary signal rather than a standalone indicator of innovation potential. In contexts with pronounced information asymmetries, codified knowledge assets and sectoral positioning remain more informative for assessing growth prospects (Drover et al., 2017; Nambisan et al., 2019). ESG disclosure can still inform screening and portfolio construction, particularly in high-scrutiny, innovation-intensive sectors (Grybauskas et al., 2022; Bridoux & Stoelhorst, 2022), but should be interpreted alongside tangible knowledge assets and sectoral context.

For policymakers and ecosystem builders, the evidence points to the need for policies that combine sustainability objectives with industry support- and knowledge-based drivers of growth. Encouraging ESG communication alone is unlikely to generate strong short-term growth effects. Policy instruments that strengthen sectoral innovation systems and knowledge infrastructures-for example, by reducing barriers to patenting and IP management, fostering specialised support services, or improving access to high-opportunity sectors (Malerba, 2002; Castellacci, 2008)-are likely to be more effective in the near term. Carefully calibrated ESG reporting frameworks for startups could, over time, enhance the credibility and informativeness of ESG disclosure, making it a more meaningful complement to structural and knowledge-based drivers (Deegan, 2019; Wang et al., 2018; Lee et al., 2024).

Boundary conditions and future research

Our contribution is bounded by several design choices and data constraints. We focus on early-stage European startups with digitalised business models, observed over a five-year window and identified through ORBIS and archived website data. The analytical sample is restricted to ventures with stable websites, usable textual content, detectable ESG terminology, and complete financial and knowledge-asset information. Our findings thus relate most directly to digitalised startups with visible online footprints, greater financial visibility, and detectable website-based ESG disclosure, rather than to the full population of nascent ventures. The comparison between the 144-firm analytical sample and the Tier-1 population indicates that the included ventures are somewhat younger but substantially more financially visible, with higher baseline revenues and similar headcounts. Inverse-probability weighting confirms that limited overlap in inclusion probabilities yields highly unstable weighted estimates, so our results should be read as conditional on archival observability and disclosure stability, rather than as representative of the full startup population. We therefore report the IPW models in the appendix only as a transparency check and do not treat the weighted estimates as a basis for substantive inference.

Our reliance on website-based ESG disclosure means that we capture communication salience rather than verified ESG performance. Although communication-based ESG measures have been validated in some contexts (Abraham et al., 2024; Wang et al., 2018), the possible gap between communication and practice is particularly salient in resource-constrained startups (Parker et al., 2019; Di Vaio et al., 2021). The results should therefore be interpreted as boundary-setting evidence on disclosure-based ESG in early-stage digital ventures, not as a general statement about ESG performance.

The cross-sectional structure of the growth models and the five-year observation window further limit causal interpretation and the detection of longer-term effects. We relate baseline characteristics to subsequent average growth, but we do not follow firms through the full venture life cycle or across major funding and scaling stages. Dynamic designs, survival analyses, and longer time horizons would be needed to examine how ESG-related practices, knowledge assets, and industry context interact over time (George et al., 2021). In particular, our exploratory H5 test should be interpreted strictly as a cross-sectional association between website-based ESG disclosure intensity and codified knowledge assets, not as evidence for or against a fully specified ESG-knowledge-growth mediation pathway.

Finally, our measures of codified knowledge assets, though richer than those typically available for startups, still rely primarily on counts and relatively coarse proxies. Disaggregating different types of intellectual property and incorporating stronger indicators of quality and appropriability would allow future research to refine the link between specific knowledge profiles and growth (Nagaoka et al., 2010; He et al., 2024). Spatial and network dimensions of startup ecosystems, such as regional knowledge clusters or inter-firm partnerships (Nambisan et al., 2019; Hellemans et al., 2022), also remain outside the scope of this study but represent promising avenues for subsequent work.

Conclusion

The research described in this paper investigated how sector-level context, codified knowledge assets, and website-based ESG disclosure intensity jointly relate to revenue and employment growth in early-stage digitalised startups. Our results indicate that sector-level context and codified knowledge assets are strongly associated with short-term growth dynamics. In contrast, website-based ESG disclosure intensity shows at most conditional and weak associations once the former factors are taken into account. We conclude by summarising our contribution, practical implications, and key limitations. Across the five hypotheses, the evidence supports the central role of codified knowledge assets (H2), finds only outcome-specific support for the sector-level growth proxy (H1), and does not support the direct, moderated, or knowledge-related association tests proposed for website-based ESG disclosure intensity (H3-H5) in the short term.

Contributions to research

The main empirical contribution is to provide boundary-setting evidence on ESG-growth relationships in early-stage digitalised startups. Using a two-tier dataset of European ventures, we find that observable short-term growth is more closely aligned with sectoral opportunity structures and codified knowledge assets than with variation in the intensity of website-based ESG disclosure. In our empirical setting, sector-level context is associated with differences in growth, and startups with richer portfolios of patents and related intellectual property capture disproportionate gains within those sectoral environments. By contrast, website-based ESG disclosure intensity does not exhibit robust direct associations with five-year revenue and employment growth once sector-level context and codified knowledge assets are accounted for, and any interactions with industry innovation intensity remain modest. Within the limits of our design, this pattern suggests that structural and knowledge-based mechanisms dominate short-term growth dynamics in digitalised startup ecosystems.

The empirical results are consistent with a KBV-and-industry-context account in which sector-level conditions shape the baseline growth environment, codified knowledge assets are most strongly associated

with firms' relative performance within that environment, and website-based ESG disclosure intensity acts as a conditional, often weak modifier. Signalling, stakeholder, and resource-dependence perspectives provide supporting interpretive context for these patterns. This account clarifies how structural, knowledge-based, and sustainability-oriented mechanisms can operate together in early-stage ventures and makes explicit that disclosure-based ESG signals, as relatively low-cost and potentially weak signals, are unlikely to displace sectoral opportunity and codified knowledge assets as the primary correlates of short-term growth. In doing so, the study contributes to a more cautious and context-sensitive theorisation of ESG-innovation relationships under the constraints of early-stage entrepreneurship.

Methodologically, we illustrate how archived website snapshots and dictionary-based content analysis can be used to construct ESG disclosure measures for startups, extending communication-based ESG metrics beyond large, listed firms. At the same time, our results underscore the limitations of this approach for detecting short-term performance effects: website-based ESG scores capture communication salience, but may not fully reflect substantive sustainability practices or their long-term consequences. This combination of feasibility and caution can guide future research designs that seek to balance measurement constraints and conceptual ambition in the study of ESG among young firms.

Practical implications

Entrepreneurs operating in this setting will be better served by prioritising sector selection and codified knowledge asset accumulation than by relying on website-based ESG disclosure intensity as a primary growth lever; investors should treat website-based ESG disclosure as a supplementary signal rather than a standalone quality indicator; and policymakers are likely to achieve stronger near-term effects by strengthening sectoral innovation systems and knowledge infrastructures than through ESG communication mandates alone.

Limitations and future research

Looking ahead, the most valuable future research would combine longitudinal designs that track ESG engagement, knowledge creation, and growth across the full venture life cycle; richer, verified ESG measures that distinguish symbolic from substantive practice; and ecosystem-level perspectives that incorporate regional knowledge clusters and inter-firm partnership structures. Together, such designs would allow researchers to test the full ESG-knowledge-growth chain that the cross-sectional H5 proxy in this study can only approximate.

Funding

No funding was received for conducting this research. Corvinus University of Budapest provided financial support only for the article processing charge (APC) and language review services.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request. Some data were obtained from licensed commercial databases and are therefore subject to third-party restrictions.

CRediT authorship contribution statement

Miklós Kozma: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Conceptualization. **Ákos Kormos:** Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Leonardo Santoro:** Writing – original draft, Conceptualization. **Krisztofer Szabó:** Writing – review & editing, Writing – original draft.

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.

Appendix A. Analytical-Sample Composition by Mapped OECD Industry Group

Table A1.

Table A1
Analytical-sample composition and variable means by mapped OECD industry group (N = 144).

Industry	N	AAGR	AAGE	Website-based ESG disclosure intensity (z)	Log-codified knowledge assets (z)	OECD-derived sector-level growth proxy	Sectoral innovation intensity (z)
Arts, Entertainment & Recreation	6	10.6%	18.6%	0.031	−0.95	4.6%	−1.30
Construction	2	75.7%	83.7%	−0.58	0.47	7.3%	−0.96
Education	10	64.2%	46.2%	−0.09	0.17	4.3%	−2.32
Electricity, Gas, Steam & AC	4	86.1%	10.4%	1.20	0.35	2.6%	−1.08
Financial & Insurance Activities	25	83.1%	25.5%	0.30	−0.06	5.5%	−0.48
Human Health & Social Work	12	18.7%	24.2%	−0.22	−0.14	6.3%	0.59
Information & Communication	37	87.4%	43.1%	−0.28	−0.16	5.0%	1.09
Main Services	19	89.2%	27.9%	0.08	0.17	3.9%	1.37
Manufacturing	6	70.8%	35.6%	0.08	0.68	4.6%	−0.18
Other Services	4	28.3%	13.3%	−0.07	−0.78	4.6%	−0.18
Professional, Scientific & Tech.	19	104.9%	63.7%	0.53	0.17	6.6%	0.62
Grand Total	144	76.1%	36.9%	0.00	0.00	5.0%	0.00

Notes: Industry groups are based on the mapped OECD industry classification used in the empirical analysis. AAGR and AAGE are five-year winsorised growth measures (revenue and employment, respectively). Website-based ESG disclosure intensity (z) is the standardised dictionary-based score derived from archived baseline-year website text. Log-codified knowledge assets (z) represent the standardised value of log(1 + total codified knowledge asset count). The OECD-derived

sector-level growth proxy is sectoral value-added growth from the OECD STAN database, mapped to firms using OECD industry categories. Sectoral innovation intensity (z) is standardised log sectoral innovation intensity. Industry-level means are descriptive only and should not be interpreted inferentially, especially for industries with small cell counts. Codified knowledge asset composition by component is reported in Table 3.

Appendix B. Selection and IPW Diagnostic Summary

This appendix reports a diagnostic summary of the inverse-probability weighting exercise used to assess observable selection into the analytical sample. The IPW exercise is treated as a diagnostic assessment, not as a corrective procedure for population-level inference.

Table B1.

Table B1
Selection and IPW diagnostic summary.

Diagnostic	Observed pattern	Interpretation
Tier 1 frame	2465 ORBIS-observable startups	Broader comparison frame
Analytical sample	144 startups	Selected disclosure-observable sample
Inclusion model variables	Age, log baseline revenue, log baseline headcount	Based on ORBIS-observable characteristics available across tiers
Main selection difference	Included firms have higher mean log baseline revenue	Analytical sample is more financially visible
Propensity-score distribution	Median ≈ 0.006	Weak overlap between Tier 1 and analytical sample
Maximum trimmed weight	>237	Extreme leverage remains after trimming
Residual imbalance	Baseline revenue SMD = 0.54 after reweighting	IPW does not achieve adequate balance
Weighted-model behaviour	High weighted R^2 and unstable coefficients	Weighted models are diagnostic only
Inference decision	Weighted models not used for substantive inference	Supports bounded external validity

Notes: IPW = inverse-probability weighting. The IPW exercise was conducted as a diagnostic assessment of observable selection into the analytical sample, not as a corrective procedure for population-level inference. Weak overlap, extreme weights, residual imbalance, and unstable weighted-model behaviour indicate that the analytical sample occupies a distinct region of the broader ORBIS-observable startup distribution. Full weighted-model results are reported in Supplementary File S1.

Appendix C. Heteroskedasticity Diagnostics

Table C1.

Table C1
Heteroskedasticity diagnostics for the nested OLS specifications.

Model	BP LM	BP df	BP *p*	White LM	W df	White *p*	N
R1	24.06	3	<.001	23.44	2	<.001	144
R2	23.93	4	<.001	23.43	2	<.001	144
R3	32.84	5	<.001	35.06	2	<.001	144
R4	33.05	6	<.001	35.00	2	<.001	144
R5	34.82	7	<.001	35.33	2	<.001	144
R6	35.44	8	<.001	32.75	2	<.001	144
E1	27.99	3	<.001	40.98	2	<.001	144
E2	29.98	4	<.001	47.16	2	<.001	144
E3	39.93	5	<.001	50.86	2	<.001	144
E4	39.67	6	<.001	51.28	2	<.001	144
E5	39.75	7	<.001	51.20	2	<.001	144
E6	39.90	8	<.001	50.36	2	<.001	144

Notes: BP = Breusch-Pagan; White = White-type heteroskedasticity test. All tests reject homoskedasticity at $p < .001$, supporting the use of HC3 heteroskedasticity-consistent standard errors for substantive inference. Focal HC3 results are reported in Table 8; full HC3 model output is reported in Supplementary File S1.

Appendix D. Count-Model Details for the Website-Based ESG Disclosure Intensity-Codified Knowledge Asset Association

Table D1.

Table D1
Negative binomial model predicting raw codified knowledge asset count.

Variable	b	SE	z	*p*	Lower 95%	Upper 95%
Intercept	1.920	0.319	6.03	<.001	1.296	2.545
Website-based ESG disclosure intensity (z)	0.094	0.073	1.29	.197	−0.049	0.238
Age	0.048	0.036	1.31	.192	−0.024	0.119
Log baseline revenue	−0.015	0.025	−0.63	.530	−0.064	0.033
Log baseline headcount	−0.115	0.074	−1.56	.118	−0.259	0.029
Dispersion (α)	0.583	0.028	20.77	<.001	0.528	0.638

Notes: Dependent variable = raw codified knowledge asset count. The model uses a log link and includes age, log of baseline revenue, and log of baseline headcount as controls. N = 144, df = 139. McFadden pseudo-R^2 = 0.031. AIC = 809.8, BIC = 827.7. Pearson χ^2/df = 0.891 (p = .816). A significant dispersion parameter α indicates overdispersion, supporting the use of a negative binomial rather than a Poisson model. Because website-based ESG disclosure intensity and codified knowledge assets are both measured at baseline, the model is interpreted as a cross-sectional association test rather than as evidence of mediation, sequencing, or temporal ordering.

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