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IT-Enabled Organisational Transformation and Green Employment Growth in Microfirms

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ABSTRACT

In this paper, we explore whether IT-enabled organisational transformation (ITOT) moderates the relationship between eco-innovation and the growth performance of microfirms. Our framework conceptualises ITOT in microfirms as a multistage process that includes: (i) setting a *digitalisation strategy*, (ii) adopting *advanced information systems technology (IST) artefacts* and (iii) developing *in-house digital resources and capabilities*. The analysis of a sample of 5015 microfirms from 39 countries indicates that eco-innovations boost firm growth when coupled with (i) a formalised digitalisation strategy, (ii) adoption of advanced IST artefacts (e.g., digital technologies that characterise Industry 4.0) and (iii) digital resources and capabilities in microfirms. These findings contribute to the growing digitalisation literature by highlighting the essential role that ITOT processes play in enabling sustainability-led growth pathways for microfirms. The paper advocates for the viability and performance benefits of a twin digital and ecological transformation and showcases the potential of ITOT for an economically successful net-zero transition that embraces microfirms.

1 | Introduction

Investigating the potential of IT-enabled organisational transformation (ITOT) for mitigating organisations' environmental impact is a growing area of interest among information systems researchers (Cooper and Molla 2017; Hanelt et al. 2017; Hedman and Henningsson 2016; Ma and Zhu 2022; Zeiss et al. 2021; among others). An aspiration to integrate 'green' and 'digital' into the industry has become the cornerstone of economic policies that are framed by the net-zero pollution imperative (European Commission 2021). Yet, empirical evidence on the relationship between firms' digitalisation efforts and their sustainability performance remains thin, leading information systems scholars to call for more research into the topic (Benitez-Amado and Walczuch 2012; Broccardo et al. 2023; Castro et al. 2021; Wang et al. 2015; Yang et al. 2018). A parallel debate in the sustainability literature is on the contingent role of digital technologies and systems for enabling sustainability-led economic growth, again triggering calls for further research into the relationship between sustainability and digitalisation (Ciulli et al. 2020; Liu et al. 2022; Tian et al. 2022).

In this paper, we bridge insights from the sustainability and digitalisation literatures to explore the potential of ITOT processes for firms' ability to jointly address their environmental and economic objectives. Focusing on eco-innovations (Rennings 2000), a particular form of sustainability practice in firms, we ask the research question, 'Does IT-enabled organisational transformation (ITOT) moderate the effects of eco-innovations on firm growth?'. The 'green growth' literature advocates for the economic opportunities in the green transition process, focusing on the potential of green transition to improve global welfare by boosting green sectors and uplifting the ecological basis for societies (Bowen and Hepburn 2014;

Capasso et al. 2019). Positioned within this green growth postulation, our paper explores the role of digitalisation as a potential enabler of green growth.[1] We are interested in the role of firms' digitalisation strategies in promoting innovation-led growth in low-carbon sectors (Fouquet 2019).

In understanding firms' digitalisation, we focus on ITOT that refers to organisational change in which IST are aligned to enhance and improve the firm's existing organisational structures and processes (Bharadwaj et al. 2013). The literature conceptualises ITOT as a competency-enhancing transformation that strengthens the firm's overall innovation processes and consequently, its economic performance (Arranz et al. 2023; Avelar et al. 2024; Nambisan and Sawhney 2007; Pavlou and El Sawy 2006). Due to its innovation-enabling capacity, ITOT is expected to act as a driver and amplifier for firms' eco-innovations that reduce the environmental impact of products, processes and activities (Rennings 2000; Kesidou and Demirel 2012; Montresor and Vezzani 2023).[2] Yet, with few exceptions, there is insufficient empirical evidence supporting ITOT's ability to enable eco-innovations (Bai et al. 2020; Díaz-Chao et al. 2021; Malhotra et al. 2013). Elliot and Webster (2017, 368) contend that 'little is known about how organisations develop and assimilate their capability to leverage Information Systems for environmental sustainability'. In addition, we highlight that very few studies explore how the interactions between firms' digitalisation and sustainability efforts affect their economic performance .

The case of small firms in general, and microfirms in particular, is relatively understudied at the interface of digitalisation and sustainability literatures. To fill this gap, we present empirical evidence based on an international dataset of 5015 microfirms (i.e., with less than 10 employees) across 39 countries. Microfirms offer a unique context for examining this research question. While they have the potential to drive green innovations due to their agility and focus on niche markets (Demirel et al. 2019; Vossen 1998), they also face obstacles such as extreme financial constraints, limited access to internal and external resources and regulatory hurdles (Beck et al. 2005). As a result, small and microfirms typically fall behind large firms in both their sustainability and digitalisation efforts, showcasing lower levels of energy efficiency, green innovations, environmental impact monitoring, adoption of off-the-shelf basic digital tools and methods and more advanced digital technologies (DESI 2022; OECD 2019, 2021). Hence, specific emphasis on microfirms and small firms is essential to ensure that this large section of the firm population (approximately 99.8% of EU businesses) is not left behind in the sustainability and digital transitions (Álvarez Jaramillo et al. 2019; Bouwman et al. 2019; Eurostat 2023; Isensee et al. 2025; Müller et al. 2018; Patma et al. 2021; Pfister and Lehmann 2023). The paper explores whether digital technologies can enable microfirms to overcome internal resource limitations by enhancing their capabilities and innovation performance, thereby enabling digital and green growth (Jibril et al. 2024).

We conceptualise ITOT in microfirms as a multistage process that encompasses (i) setting a *digitalisation strategy*, (ii) adopting *information systems and technologies (IST)* and (iii) developing *digital resources and capabilities*. Our analysis highlights three important mechanisms in which ITOT can enable microfirms' sustainability-driven growth. First, we show that eco-innovations can boost firm growth when microfirms are coupled with a formalised *digitalisation strategy*, rather than relying solely on digital operations. Second, we pinpoint that the adoption of *advanced IST*, rather than basic IST, allows microfirms to grow out of their eco-innovation investments. Third, we provide evidence that the relationship between eco-innovation and firm growth is reinforced by firms' *internal* digital resources and capabilities.

The paper makes three contributions to the cross-section of digitalisation and sustainability literatures. First, we extend the information systems literature, which highlights firms' digital capabilities and the sophistication of IST as important enablers of firms' financial and innovation performance (Hanelt et al. 2017), with evidence that ITOT can also contribute to firms' environmental sustainability. Second, even though the sustainability literature acknowledges the importance of the broader socio-economic and technological circumstances to promote growth (Colombelli et al. 2021), the implications of digitalisation are frequently overlooked with a few exceptions (Bai et al. 2020; Díaz-Chao et al. 2021). We contribute to the sustainability literature with evidence-based insights showing that digitalisation is one of the most essential circumstances for enabling growth in microfirms. Finally, with a specific focus on microfirms—an overlooked subset of firms despite accounting for a significant share of employment and revenues globally as well as the overall environmental impact (Koirala 2019; OECD 2021)—the paper highlights mechanisms for ITOT to drive microfirms' growth. As such, the paper contributes to recent literature that emphasises the need to align sustainability and digitalisation efforts for an economically successful net-zero transition (Achi et al. 2022; Alraja et al. 2022; Chaudhuri et al. 2022; Jibril et al. 2024).

2 | Review of the Literature

2.1 | ITOT and Microfirms

Studies on ITOT seek to understand how organisations can better align their IT capabilities and infrastructures with their strategic objectives (Bharadwaj et al. 2013; Nambisan et al. 2017). The assumption is that when appropriately aligned to the organisational strategies, ITOT contributes to significant performance improvements in firms, including higher levels of innovation, productivity, profitability, growth, customer satisfaction and loyalty (Wessel et al. 2021). Information systems literature increasingly differentiates between ITOT and digital transformation (DT) (Baiyere et al. 2020; Hanelt et al. 2021; Markus and Rowe 2021; Salmela et al. 2022; Weill et al. 2021). While ITOT is understood as a competency-enhancing organisational change where information technologies are aligned to support the firm's existing organisational structures and processes for better performance (Bharadwaj et al. 2013), DT is seen as a competency-destroying change led by IT to radically transform the firm's business models, value offering and sometimes even shift its main industry of operation (Baiyere et al. 2020; Hanelt et al. 2021; Weill et al. 2021). Baiyere et al. (2020) liken ITOT to a lion 'cub transforming into a lion—that is into a faster and more efficient version' of itself, while they liken DT to 'the metamorphosis of a larva into a butterfly' (p. 253). It is important to note that true DT is extremely rare among organisations (Baiyere et al. 2020).

This paper deliberately focuses on ITOT, which is more widely diffused across firm populations, especially among the resource-restrained microfirms that form the empirical focus of this paper. Microfirms lag behind in their digitalisation levels and efforts. The literature and recent data on ITOT of SMEs indicate that they adopt and implement information technologies and systems at significantly lower levels compared to large firms due to resource limitations (DESI 2022). As a result, they display lower and often insufficient levels of digital capabilities, skills and routines (Bai et al. 2020; Bidan et al. 2012; Soluk and Kammerlander 2021; Cenamor et al. 2019; Gurbaxani and Dunkle 2019; Moeuf et al. 2020; OECD 2019). For example, only one-third of European SMEs report having Enterprise Resource Planning or Customer Relationship Management software, indicating that there is still much room for ITOT to generate important efficiency and productivity gains among SMEs (DESI 2022).[3]

2.2 | ITOT and Sustainability

The sustainability stream of the information systems literature has shown significant growth over the last decade (Cooper and Molla 2017; Hedman and Henningsson 2016; Hanelt et al. 2017; Neri et al. 2023; Zeiss et al. 2021). In particular, efficiency improvements associated with ITOT have led scholars to suspect that ITOT can 'fully unlock industrial sustainability' (De Sousa Jabbour et al. 2018, 18). These ITOT-led sustainability gains occur via cutting waste and energy consumption thanks to improved data flows, data sharing, ability to trace products, waste and by-products in the supply chain as well as facilitating intelligent disassembly of parts for reuse and recycling (Bai et al. 2020; Brozzi et al. 2020; Corbett and Mellouli 2017; Di Maria et al. 2022; Díaz-Chao et al. 2021; Seidel et al. 2013; Zeiss et al. 2021). The empirical evidence points to three areas where the ITOT investments into sustainability can drive organisation-level performance and competitiveness: (1) cost reductions through higher efficiency in internal operations, (2) enhanced corporate reputation through better management of corporate social responsibility and (3) generating product eco-innovations that can help the company differentiate itself from competitors (Bag et al. 2020; Loeser et al. 2017; Santoalha et al. 2021).

Despite these broader expectations for alignment between ITOT, corporate sustainability efforts and firm performance, recent studies point to the complex relationship between these (Ding et al. 2024). For example, studies show that the environmental benefits of ITOT might be limited to certain sectors or types of digital technologies and limited by resource restrictions (Ardito et al. 2021; Bai et al. 2020; Díaz-Chao et al. 2021). Przychodzen et al. (2018) show that, like most investments, the performance outcomes of green IT investments are not always immediate and can occur with significant time lags. Additionally, several studies highlight the growing concerns around the environmental impact of digitalisation due to increased emissions and e-waste (Bohnsack et al. 2022; Lange et al. 2020; Seidel et al. 2013). Hence, the potential for ITOT to support the sustainability-led growth of firms requires further investigation.

2.3 | Conceptual Framework and Hypotheses

The premise of sustainability-led growth is based on the 'win–win' assumption of the Porter hypothesis, which suggests that firms will grow as a result of introducing eco-innovations and therefore, can address their environmental and economic objectives simultaneously (Porter and Van der Linde 1995). In this context, eco-innovations could promote growth by increasing market share and reducing production costs. Yet, the literature presents mixed findings on the impact of eco-innovations on firms' economic performance, casting doubt on the feasibility of an eco-innovation-driven growth trajectory for firms in practice (Ghisetti 2018; Kunapatarawong and Martínez-Ros 2016; Stucki 2019). Some of these studies highlight the positive impact of eco-innovations on firm performance (Colombelli et al. 2021; Geng et al. 2021; Horbach and Rammer 2020; Huang and Li 2017), while others report evidence for no significant or even negative economic returns to eco-innovation investments (e.g., Aguilera-Caracuel and Ortiz-de-Mandojana 2013; Rexhäuser and Rammer 2014). These studies typically employ large samples of firm data from European countries or China in a panel data format and focus on economic performance measures based on firm sales, employment or profitability. In particular, we highlight Kunapatarawong and Martínez-Ros (2016) and Horbach and Rammer (2020), which focus on firms' employment growth. We also note that the literature does not cover the case of SMEs, and especially microfirms facing significant growth constraints, to investigate whether they are more likely to grow if they engage with eco-innovation.

In line with Hanelt et al. (2021), we build on the contingency approach to account for the holistic confluence of different aspects of ITOT that may moderate the relationship between eco-innovations and microfirm performance. This conceptualisation builds on a small number of studies that indicate that firms' digitalisation strategies and capabilities moderate how firm sustainability affects economic performance (Torrent-Sellens et al. 2023). The contingency approach highlights three key issues regarding organisational performance: (a) There is not one best way to organise, (b) a specific way of organising is not equally effective under all conditions and (c) the most effective organisational structures should be appropriate to the work performed and to the environmental conditions facing the organisation. (Schoonhoven 1981; Galbraith 1973). Here, we point to the importance of the contingencies that moderate the relationship between eco-innovation and microfirm performance. For instance, Dixon-Fowler et al. (2013) emphasise the need to better understand the contingencies that can enable a sustainability-led growth pathway for the economy. This requires a deeper comprehension of the broader circumstances that microfirms operate under, such as the regulatory and institutional regimes and competition dynamics (Colombelli et al. 2021; Kunapatarawong and Martínez-Ros 2016), as well as the internal factors such as firm constraints, capabilities and strategies (Demirel and Danisman 2019; Jové-Llopis and Segarra-Blasco 2018).

Aligned with the latter category of microfirm-specific enablers of sustainability-led growth, this paper focuses on the contingent role of ITOT. In doing so, we aim to bridge the sustainability and information systems literatures. We conceptualise ITOT through microfirms' (1) having a formal digitalisation strategy, (2) sophistication of IST adoption and implementation and (3) digital resources and capabilities. We then investigate how ITOT moderates the relationship between microfirms' eco-innovation and growth performance, as outlined in Figure 1.

2.3.1 | Digitalisation Strategy

The first dimension of ITOT we consider in this paper is the *strategic approach towards digitalisation*, defined as 'organisational strategy formulated and executed by leveraging digital resources to create differential value' (Bharadwaj et al. 2013, 472). Previous studies show that treating digitalisation at the strategic rather than operational level enhances firm innovation and performance (Moeuf et al. 2020; Somohano-Rodríguez et al. 2020) and facilitates a swift transformation (Hanelt et al. 2021). Bharadwaj et al. (2013) argue that organisations with a formalised and well-defined strategic approach to ITOT recognise the pervasiveness of digital resources across all activities, functions and products. Such firms treat digital resources as strategic resources instead of just systems and technologies. In the context of SMEs, Somohano-Rodríguez et al. (2020) find that a strategic approach in ITOT facilitates careful consideration and planning of the company's economic and non-economic objectives and the deployment of digital technologies strategically in the required areas. It is increasingly understood that treating digitalisation at the strategic level rather than a merely functional or technical issue is essential to reap the full benefits from investments in ITOT (Benitez-Amado and Walczuch 2012; Cenamor et al. 2019; Warner and Wäger 2019).

Having a strategic approach towards ITOT implementation is likely to amplify the success and impact of the firms' sustainability efforts by enabling holistic change across departments, systems, products and services (Matt et al. 2015). Having a formalised digitalisation strategy led by the company's executive managers allows microfirms to place ITOT at the forefront of the organisational processes, facilitating the penetration of ITOT into organisational learning and innovation activities across all initiatives, including sustainability (Hanelt et al. 2021; Kane 2019). Information systems scholars emphasise the need for a strategic alignment of IT investments with the firm's broader objectives to reap the synergistic benefits across different domains such as innovation and sustainability (Dao et al. 2011; Gerow et al. 2015; Goni et al. 2017). In this vein, Malhotra et al. (2013, 1265), for example, argue that 'strategic IS for environmental sustainability allows companies to proactively transform value chain activities to benefit society both economically and environmentally'. Likewise, Bordeleau et al. (2021) indicate the presence of possible links between strategic uses of information and communication technologies for transforming the organisation to be purpose-driven.

A strategic approach can further enable microfirms to deliberately evaluate scenarios about the distant future, allowing them to override the short-termism that is typical in resource-constrained settings of small firms. Therefore, one expected benefit of the strategic approach to digitalisation in microfirms is its ability to identify issues and risks, such as climate change, that the firm needs to tackle in the distant future (Power and Gruner 2017).

Hence, we hypothesise that microfirms with a strategic approach towards digitalisation are more likely to make connections between their ITOT efforts and eco-innovations and reap the benefits of synergies between these, enabling growth opportunities.

H1. *A strategic approach towards digitalisation positively moderates the effects of eco-innovation on microfirm growth.*

2.3.2 | Sophistication of IST

The second dimension of ITOT that we consider as a moderator in this paper relates to the sophistication of its technological artefacts. A range of advanced digital technologies such as

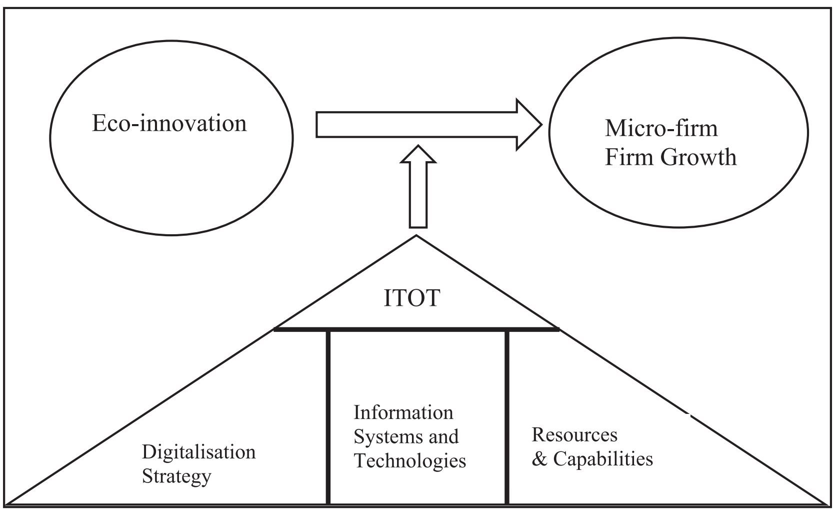

FIGURE 1 | Conceptual model.

blockchain technologies, robotics, automation, AI and big data, cyber-physical systems and the Internet of Things (IoT) (Li et al. 2020; Günther et al. 2017) are at the root of ITOT which can help organisations create distinctive value propositions that leverage data, software services and digitally augmented products (Hanelt et al. 2021; Weill et al. 2021). Companies increasingly use these digital technologies and platforms to enhance their innovation capabilities, business models and efficiency (Kane 2019). At the same time, despite the wide diffusion of IST across sectors since the 1990s, advanced IST applications that can create genuine value remain concentrated in a small subset of firms that are at the technological frontier (Cockburn et al. 2018; Somohano-Rodríguez et al. 2020; Pilat and Criscuolo 2018). For example, a recent survey of EU firms finds that AI is used by only 28% of large firms and 7% of SMEs while IOT applications can be found in 48% of large firms and 28% of SMEs (DESI 2022).

Basic IST, on the other hand, is more widely diffused across SMEs and large firms: For example, cloud computing is used by 72% of large firms and 40% of SMEs; high-speed internet is available to 95% of large firms and 80% of SMEs (DESI 2022; Somohano-Rodríguez et al. 2020). The heterogeneity in the sophistication of the IST adoption across firms can result in performance differentials in firms (Bidan et al. 2012). Information systems scholars have shown that only advanced forms of IST implementation led to enhanced business performance, product and process innovation (Nambisan and Sawhney 2007; Pavlou and El Sawy 2006). For instance, more recently, Trantopoulos et al. (2017) provide evidence that IST that expands the network connectivity enables firms to realise economic gains from process innovations by allowing them to search deeply multiple external sources.

We argue that the sophistication of the IST artefacts is a moderator of how eco-innovation affects firm growth. The main rationale for this argument is that the relationship between IST and environmental sustainability is reported to be conditional on the type of IST adopted (Seidel et al. 2013) and how advanced the degree of digitalisation is (Ardito 2023). Higón et al. (2017) explain that basic IST, such as computers and off-the-shelf software, negatively correlate with sustainability indicators such as CO_2, energy consumption and e-waste of IST machinery and devices. On the other hand, the openness, flexibility, malleability and generativity affordances of advanced IST can facilitate many previously unforeseen possibilities, some of which can be used to enhance sustainability outcomes through cleaner production and circular economy business models (Hanelt et al. 2017, 2021; Kirchherr et al. 2017). In a study of more than 150,000 Italian firms, Montresor and Vezzani (2023) show that advanced IST, such as the Internet of things and interactive technologies, drive eco-innovations, while basic IST, such as internet access, has no impact. For instance, embedding advanced IST, such as AI, into the production process can make it more sustainable as firms can monitor resource and energy use and manage their emissions better (Gunasekaran and Gallear 2012). Hence, advanced IST (e.g., smart manufacturing) could promote both the levels and effectiveness of eco-innovations and enhance efficiencies around resources, materials and energy use (Alcayaga et al. 2019). Chen et al. (2023) argue that through enhancing resource efficiencies and seamlessly integrating new business operations for these efficiencies, advanced IST can help firms incorporate eco-innovations and thereby improve their economic performance measured in terms of costs of materials and energy, increasing rates of return and earnings per share. We further extrapolate that improved performance in these fields is likely to be reflected in the firm's growth performance.

Hence, we expect advanced IST to support sustainability more compared to basic IST, thereby creating opportunities to drive the growth of microfirms.

H2. *Adopting advanced IST positively moderates the effects of eco-innovation on microfirm growth.*

2.3.3 | Digital Resources and Capabilities

A third dimension of ITOT that is covered in this paper is the digital resources and capabilities that firms require to implement ITOT effectively (Proksch et al. 2021; Vial 2019). Digital resources and capabilities are defined as the bundles of unique resources—such as skills, learning, routines, processes and systems—required for implementing ITOT (Gurbaxani and Dunkle 2019). These form the foundations of firms' IST capabilities, digital platform capabilities and human–machine interaction capabilities that are essential to survive and grow in markets (Hanelt et al. 2021).

Salmela et al. (2022) and Kane (2019) emphasise that resources and capabilities (both human and technological) are needed for ITOT to enable agility and generate value in organisations. The resource-based view posits that firm performance differences stem from unique, difficult-to-imitate resources and capabilities (Barney 1991), emphasising the need for these capabilities to be continuously renewed for sustained competitiveness (Teece 2007). Extensions of the resource-based view are echoed in the sustainability and digitalisation literatures where studies argue that unique firm capabilities are at the source of firms' sustainable DT (Feroz et al. 2023; Soluk and Kammerlander 2021).

In relation to their moderating role, we argue that digital resources and capabilities are essential to facilitate the decoupling of economic growth and climate change (Cai et al. 2013; Faucheux and Nicolaï 2011). Therefore, these capability and resource-based aspects of ITOT implementation are expected to have a positive moderating role for the eco-innovation—firm performance relationship as postulated in Torrent-Sellens et al. (2023). Castiaux (2012) demonstrates that dynamic digital capabilities help firms sense and seize green opportunities, thereby creating pathways for economic benefits out of green opportunities. In a more recent study, Díaz-Chao et al. (2021) emphasise that firms' digital resources and capabilities drive their environmental actions and investments, resulting in firm performance and growth. Similarly, Chari et al. (2022) highlight the role of joint dynamic capabilities at the root of digitalisation and sustainability as an enabler of firm performance.

Hence, our investigation hypothesises a positive relationship between eco-innovation and growth when microfirms have internal digital resources and capabilities.

H3. *Internal digital resources and capabilities positively moderate the effects of eco-innovation on microfirm growth.*

3 | Research Methodology

3.1 | Empirical Context: Microfirms

This paper focuses on microfirms with less than 10 employees, an often-overlooked subset of the firm population. The environmental impact and economic potential of small firms are undeniable, with SMEs accounting for 60%–70% of industrial pollution, 99.7% of all firms in the OECD area and 45%–78% of all employment in emerging and low-income economies (Koirala 2019). More than half of the economic impact, both in numbers and employment figures can be attributed to microenterprises (OECD 2019). Additionally, the eco-innovation potential of microfirms has been recognised in environmental entrepreneurship literature, with particular emphasis on their radical innovation potential for sustainability transitions (Demirel et al. 2019).

3.2 | Data and Sample

To understand whether the eco-innovation and firm growth relationship is contingent on ITOT, we rely on data from the 'Flash Eurobarometer 486: SMEs, start-ups, scale-ups and entrepreneurship' survey. The survey is undertaken by the European Commission and covers 16,365 enterprises from various sectors. It is conducted in 39 countries between February and May 2020.[4]

When generating our sample, we focus on the microfirms (i.e., with less than 10 employees), consisting of 5015 microfirms from 39 countries. Besides the need to provide evidence on the growth and innovation dynamics of microfirms (Farè 2022), we focus on microfirms because they are the only firms with available (continuous) data on employment growth in this dataset. Consequently, we exclude firms in the dataset with missing data on employment growth. We then filter the dataset to ensure that complete data are available for each firm and all variables of interest, resulting in a final balanced sample of 5015 microfirms. Table A1 Panel A presents the list of countries and the respective number of firms from each country, and Panel B presents the industry breakdown using NACE categories.

3.3 | Variables

Table 1 presents the descriptive statistics of the variables, and Table A2 displays the detailed descriptions of the variables.

3.3.1 | Dependent Variable

We use firm growth as our dependent variable and generate a continuous employment growth variable (*GROWTH*) measured as the percentage growth in firm employees between 2017 and 2020. Employment growth is likely to provide a more accurate picture of growth for small businesses due to common revenue fluctuations especially at early stages (Coad and Hölzl 2012). We observe in Table 1 that the average *GROWTH* in our sample is 1.70%, with a standard deviation of 39.16%, indicating a high level of variability.

3.3.2 | Explanatory Variables

The main explanatory variables to test our hypotheses are the ones that represent firms' *eco-innovation* and *ITOT* efforts. Our eco-innovation variable (*EI*) is a binary variable that equals 1 if the firm reports actively developing sustainable products or services and 0 otherwise.[5] Table 3 shows that 32% of the firms in our sample report eco-innovating.

Regarding the ITOT variables, first, to test H1, we generate a variable that equals 1 if the enterprise has a formal DT strategy (*DIGIT-STRATEGY*) and 0 otherwise. Table 3 shows that, on average, 26% of the firms report having a DT strategy. Second, to account for the sophistication of IST (H2), we use a categorical variable (*DIG-LEVEL*) classified into four levels (1–4) where Level 1 corresponds to firms that adopted basic IST (information technology for data processing and communications such as cloud computing and cybersecurity) and Level 4 to the adoption of *advanced* IST (robotics, automation and information technology for data collection and transmission between devices such as IoT cyber-physical systems and embedded technologies). Firms that report Level 2 in response to this question have implemented basic IST and recognise a need to adopt advanced IST but have no plans to adopt advanced IST due to financial limitations and skills shortages. On the other hand, firms that report at Level 3 have implemented basic IST and are considering adopting advanced IST. Table 1 and Figure A1 indicate that 46% of the firms in our sample have adopted only basic digital technologies and 30% of the firms have already adopted advanced ones.

Third, as a proxy of firms' digital resources and capabilities (H3), we use a survey question based on self-reported barriers to digitalisation. Firms reporting only internal barriers to digitalisation are identified as lacking unique resources and capabilities. To better isolate the impact of internal barriers, we also examine cases where firms face only external barriers and cases where they face both internal and external barriers. This approach provides a more comprehensive view of the digitalisation challenges microfirms face, acknowledging that internal digital resources and capabilities are often influenced and constrained by external factors. Cases where firms only report the barriers of (1) *lack of skills*, (2) *lack of financial resources* or (3) *internal resistance* to change are classified as internal barriers to digitalisation (*INT-BARR ONLY*), as they reflect in-house resource and capability barriers. By contrast, when firms only report external barriers to digitalisation such as (1) *regulatory obstacles*, (2) *lack of IT infrastructures such as high-speed internet connection*, (3) *IT security challenges* or (4) *uncertainty about future digital standards*, these are classified as external barriers to digitalisation (*EXT-BARR*), as they reflect barriers beyond the firms' organisational boundaries. Finally, we construct a third category to capture those firms that report both internal and external barriers (*BOTH-BARR*). Table 3 reveals that 19% of the firms report internal barriers only, 17% report external barriers only and 24% face both barriers.[6]

TABLE 1 | Descriptive statistics.

Variable	Obs.	Mean	Min	Max	Stand. Dev.
GROWTH (%)	5015	1.70%	−146.63%	160.94%	39.16%
EI	5015	0.32	0	1	0.47
DIGIT-STRATEGY	5015	0.26	0	1	0.44
INT-BARR ONLY	5015	0.19	0	1	0.39
EXT-BARR ONLY	5015	0.17	0	1	0.38
BOTH-BARR	5015	0.24	0	1	0.43
DIG-LEVEL	3869		1	4	1.31
DIG-LEVEL = 1	1770 (46%)				
DIG-LEVEL = 2	444 (11%)				
DIG-LEVEL = 3	507 (13%)				
DIG-LEVEL = 4	1148 (30%)				
SIZE (t − 3)	5015	1.53	0.69	4.88	0.52
AGE	5015	20.27	0	164	17.29
STRAT-FOCUS	5015	0.33	0	1	0.47
GOODS	5015	0.40	0	1	0.49
PATENTEE	5015	0.05	0	1	0.22
EXPORTER	5015	0.28	0	1	0.45
OWNED > 1	5015	0.42	0	1	0.49
EQUITY-OWNED	5015	0.01	0	1	0.11
FAMILY-OWNED	5015	0.21	0	1	0.41
REGION-BUS-ENV	5015		1	4	0.67
REGION-BUS-ENV = 1	146 (3%)				
REGION-BUS-ENV = 2	707 (14%)				
REGION-BUS-ENV = 3	3186 (64%)				
REGION-BUS-ENV = 4	976 (19%)				
SUSTAINABLE-STRAT	5015	0.41	0	1	0.49
INCOMPAT-BUSINESS	5015	0.21	0	1	0.41

3.3.3 | Control Variables

To reduce unobserved heterogeneity, we use a set of control variables that are selected from the widely accepted indicators in firm growth studies (Coad and Hölzl 2012; Colombelli et al. 2021).

First, we control for firm size (*SIZE (t − 3)*), as larger firms may have more resources to invest in both eco-innovation and digitalisation, influencing growth outcomes (Coad and Hölzl 2012). Next, we control for firm age (*AGE*), which represents the number of years since establishment. Older firms with more experience may benefit from established processes and market presence, impacting their growth potential (Colombelli et al. 2021). We include a binary variable indicating whether a firm has a strategic growth plan (*STRAT-FOCUS*), as strategic planning is linked to better performance and growth outcomes (Wiklund and Shepherd 2003). We also control for whether the firm primarily provides goods (*GOODS*) rather than services, as firms providing goods, such as manufacturing firms, often exhibit different growth patterns compared to service firms due to their distinct operational and market characteristics (Audretsch et al. 2004).

Additionally, we control for whether the firm holds a patent or has a patent application (*PATENTEE*), because patents are often associated with higher firm growth due to the competitive advantage they provide (Czarnitzki and Delanote 2013). We also control whether the firm exports goods or services to international markets (*EXPORTER*), which can enhance growth through access to larger markets (Roper and Love 2002).

We also control for some ownership characteristics such as whether more than one person owns the firm (*OWNED > 1*), whether the firm is equity owned (*EQUITY-OWNED*) and whether it is predominantly family owned (*FAMILY-OWNED*). Studies show that ownership structure can significantly influence firm performance and growth (Miller et al. 2007). Finally, we control for geographical differences by including the strength of the regional business environment (*REGION-BUS-ENV*),[7] as a supportive regional business environment is crucial for firm growth, providing necessary infrastructure and market conditions (Fritsch and Storey 2014).

Table A3 presents the correlation coefficients among the variables and indicates no major collinearity problems.

3.4 | Econometric Approach

To analyse whether the relationship between eco-innovations and firm growth is contingent on ITOT in microfirms, we use cross-sectional estimation techniques that suit the nature of the dataset. Because firms' strategic decisions are often co-determined, endogeneity presents as a potential issue in estimations (Ozusaglam et al. 2018). Specifically, we need to consider that the relationship between eco-innovation and firm growth is subject to selection bias (Darnall and Kim 2012). To account for endogeneity, we use a two-stage model and employ the instrumental variable two-stage least-squares (IV-2SLS) estimator (Greene 2008). We consequently estimate two separate models. The first equation uses the eco-innovation variable, *EI*, as a dependent variable. The exogenous instruments for the variable *EI* and other control variables are used to estimate the predicted *EI* variable for each firm. For this purpose, we calculate the following models:

$$EI_i = \alpha_o + \alpha_1 X_i + \alpha_2 Y_i + \delta_j + \emptyset_k + \varepsilon_i, \quad (1)$$

$$GROWTH_i = \beta_o + \beta_1 \widehat{EI}_i + \beta_2 Y_i + \delta_j + \emptyset_k + \varepsilon_i, \quad (2)$$

where i, j and k denote firm, country and industry, respectively. X stands for the instrumental variables, and Y for the explanatory and control variables that are introduced in the previous section. $\widehat{EI}$ indicates the predicted eco-innovation variable from the first stage (Equation 1). δ_j and $\varnothing_k$ show the country and industry dummies that account for differences across countries and industries. The inclusion of the industry indicator variables enables us to isolate the moderating effect of digitalisation on the relationship between eco-innovation and firm growth while controlling for the differences in industry-specific characteristics. We cluster the standard errors at the industry level.

For instrumental variable regressions, we use two separate firm-level variables, *SUSTAINABLE-STRAT* and *INCOMPAT-BUSINESS* as instrumental variables for *EI*. They, respectively, indicate whether the firm has a strategy or action plan to become a sustainable enterprise (*SUSTAINABLE-STRAT*)[8] and whether it is facing a sustainability barrier in terms of having an incompatible business model (*INCOMPAT-BUSINESS*). We expect that microfirms with a strategy to become sustainable enterprises are more likely to allocate resources and internal efforts towards eco-innovation (Leonidou et al. 2017). Furthermore, microfirms that face sustainability barriers due to not having compatible business models would be less likely to adopt eco-innovations. Therefore, our instruments satisfy the relevance condition. However, it is not necessarily the case that the firms with a sustainable strategy or such sustainability-incompatible business models are growing more (or less), meeting the exclusion criterion. The validity of the instruments is tested for overidentification, and we also test for whether they are weak.

4 | Results and Discussion

In this section, we present our findings regarding whether a positive relationship between eco-innovation and firm growth is contingent on microfirms' ITOT efforts. In doing so, we focus on the formerly discussed three aspects of ITOT: (1) digitalisation strategy, (2) sophistication of IST and (3) digital resources and capabilities.

4.1 | The Effects of Digitalisation Strategy

First, we test whether the presence of an explicit digitalisation strategy affects firms' ability to reap growth benefits out of their eco-innovation efforts (H1) in Table 2. Columns 1 and 2 display the case when a digitalisation strategy is present (i.e., when *DIGIT-STRATEGY* equals 1). Columns 3 and 4 present the results when a digital strategy is missing (i.e., when *DIGIT-STRATEGY* equals 0). The coefficient of *EI* is significant at the 1% level only in Column 2 where firms indicate the presence of a digital strategy. It is insignificant when such a strategy does not exist (Column 4), indicating that eco-innovations only boost firm growth in the presence of a formalised digitalisation strategy.

These results are in line with the recent findings in the literature that document the growing importance of approaching digitalisation at the strategic level, contrary to a merely technical or operational approach (Cenamor et al. 2019; Moeuf et al. 2020; Somohano-Rodríguez et al. 2020). In terms of economic magnitude, we observe in Column 2 that eco-innovation increases firm growth by 0.28% when digital strategic thinking is present compared to the case when such a strategy is not present.[9] Considering that the average firm growth in our sample is 1.70%, such an effect is economically significant, corresponding to 17% of the average value of firm growth.[10]

Finally, Columns 5 and 6 present the first-stage and second-stage results when an interaction term (*EI*DIGIT-STRATEGY*) is used instead of split samples. The coefficient of the interaction *EI*DIGIT-STRATEGY* is positive and significant at the 1% level, confirming our previous findings.

4.2 | The Effects of Sophistication of IST

Next, we test if growth through eco-innovations is driven by the adoption of advanced IST, rather than basic IST (H2). Table 3 shows the findings of the second-stage IV-2SLS estimations while first-stage regression findings are reported in Table A4. Columns 1–4 in Table 3 present the results using Equation (2) when *DIG-LEVEL* equals 1–4, respectively. We observe that

TABLE 2 | Effect of digital transformation strategy on the relationship between eco-innovation and growth.

Dependent variable: *GROWTH*	(1) *DIGIT-STRATEGY* = 1 First stage	(2) *DIGIT-STRATEGY* = 1 Second stage	(3) *DIGIT-STRATEGY* = 0 First stage	(4) *DIGIT-STRATEGY* = 0 Second stage	(5) *Interaction* First stage	(6) *Interaction* Second stage
EI		0.282**		0.048		0.084
		(0.11)		(0.06)		(0.06)
DIGIT-STRATEGY						−0.046*
						(0.03)
*EI*DIGIT-STRATEGY*						0.128**
						(0.06)
SIZE (*t* − 3)	0.003	−0.476***	−0.003	−0.407***	0.001	−0.426***
	(0.03)	(0.04)	(0.01)	(0.03)	(0.01)	(0.01)
AGE	0.000	−0.001	−0.001	−0.000	−0.001	−0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
STRAT-FOCUS	0.118***	0.012	0.099***	0.050***	0.119***	0.037***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
GOODS	0.013	−0.008	0.006	0.025**	0.013	0.017
	(0.03)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
PATENTEE	0.146***	−0.006	0.121***	0.024	0.143***	0.013
	(0.05)	(0.03)	(0.04)	(0.05)	(0.03)	(0.02)
EXPORTER	0.048	0.039	0.028*	0.039***	0.037*	0.037***
	(0.05)	(0.03)	(0.01)	(0.01)	(0.02)	(0.01)
OWNED > *1*	0.015	0.065***	0.008	0.075***	0.008	0.073***
	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)
EQUITY-OWNED	0.057	0.074	0.168**	0.029	0.117**	0.046
	(0.04)	(0.06)	(0.07)	(0.04)	(0.05)	(0.04)
FAMILY-OWNED	0.038	−0.035	0.066***	−0.039**	0.059**	−0.039***
	(0.04)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)

(Continues)

TABLE 2 | (Continued)

Dependent variable: ***GROWTH***	**(1)** ***DIGIT-STRATEGY = 1***	**(2)** ***DIGIT-STRATEGY = 1***	**(3)** ***DIGIT-STRATEGY = 0***	**(4)** ***DIGIT-STRATEGY = 0***	**(5)** ***Interaction***	**(6)** ***Interaction***
	First stage	**Second stage**	**First stage**	**Second stage**	**First stage**	**Second stage**
REGION-BUS-ENV = 2	0.033	−0.026	−0.042*	0.068**	−0.025	0.048
	(0.12)	(0.07)	(0.02)	(0.03)	(0.03)	(0.03)
REGION-BUS-ENV = 3	−0.014	0.061	−0.023	0.135***	−0.016	0.117***
	(0.11)	(0.07)	(0.03)	(0.03)	(0.02)	(0.03)
REGION-BUS-ENV = 4	0.017	0.118	0.012	0.149***	0.015	0.145***
	(0.13)	(0.07)	(0.03)	(0.03)	(0.03)	(0.03)
SUSTAINABLE-STRAT	0.167***		0.141***		0.154***	
	(0.03)		(0.02)		(0.02)	
INCOMPAT-BUSINESS	−0.077***		−0.077***		−0.076***	
	(0.02)		(0.01)		(0.01)	
Constant	0.442***	0.725***	0.085	0.527***	0.090	0.604***
	(0.14)	(0.14)	(0.10)	(0.05)	(0.07)	(0.09)
R^2	0.164	0.284	0.140	0.302	0.161	0.324
Number of firms	1323	1322	3701	3693	5024	5015
First-stage *F* statistic	15.59***		63.97***		742.36***	
Wu–Hausman *F* statistic		17.48***		109.87***		8.39***
Sargan statistic		0.02		0.26		0.02
Sargan *p* value		0.89		0.61		0.96

Note: Results display the influence of digital transformation strategy (*DIGIT-STRATEGY*) on the eco-innovation (*EI*) and firm growth (*GROWTH*) relationship. We use two-stage models to control selection bias and use the instrumental variable two-stage least-squares (IV-2SLS) estimators. Columns 1 and 2 display the first- and second-stage regressions and consider the case when digital strategic thinking is present in the firms, that is, when *DIGIT-STRATEGY* equals 1. Columns 3 and 4 incorporate the first- and second-stage regressions when digital strategic thinking is not present, that is, when *DIGIT-STRATEGY* equals 0. Columns 5 and 6 present the first stage and second stage results when an interaction term (*EI*DIGIT-STRATEGY*) is used instead of split samples. Standard errors clustered at the industry level in parentheses.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

TABLE 3 | The effect of the sophistication of informational technologies and systems.

Dependent variable: *GROWTH*	(1) *DIG-LEVEL* = 1	(2) *DIG-LEVEL* = 2	(3) *DIG-LEVEL* = 3	(4) *DIG-LEVEL* = 4	(5) *Interaction*
EI	−0.065*	−0.025	0.462*	0.216***	0.126*
	(0.04)	(0.19)	(0.24)	(0.08)	(0.07)
DIG-LEVEL					0.016***
					(0.00)
EI * *DIG-LEVEL*					0.012**
					(0.00)
SIZE (*t* − 3)	−0.382***	−0.499***	−0.465***	−0.495***	−0.437***
	(0.04)	(0.05)	(0.08)	(0.06)	(0.01)
AGE	−0.001	−0.002	−0.000	0.000	−0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
STRAT-FOC	0.057***	0.116***	−0.056	0.027	0.041***
	(0.02)	(0.04)	(0.09)	(0.02)	(0.02)
GOODS	0.061***	−0.084*	−0.001	−0.023**	0.011
	(0.01)	(0.05)	(0.06)	(0.01)	(0.01)
PATENTEE	0.088	0.005	0.009	−0.030	0.011
	(0.08)	(0.06)	(0.08)	(0.04)	(0.03)
EXPORTER	0.026	0.099*	0.048	0.033	0.038***
	(0.03)	(0.05)	(0.05)	(0.02)	(0.01)
OWNED > *1*	0.043***	0.065**	0.104***	0.082***	0.072***
	(0.01)	(0.03)	(0.03)	(0.03)	(0.01)
EQUITY-OWNED	0.107	−0.139	−0.100	0.022	0.005
	(0.10)	(0.09)	(0.26)	(0.07)	(0.05)
FAMILY-OWNED	−0.020	0.021	−0.082*	−0.068***	−0.041***
	(0.02)	(0.06)	(0.05)	(0.02)	(0.02)
REGION-BUS-ENV = 2	0.026	−0.040	−0.135	0.012	−0.007
	(0.02)	(0.04)	(0.09)	(0.03)	(0.04)
REGION-BUS-ENV = 3	0.102***	0.038	0.010	0.040	0.065*
	(0.03)	(0.05)	(0.07)	(0.04)	(0.03)
REGION-BUS-ENV = 4	0.128***	0.069*	−0.009	0.074	0.093***
	(0.03)	(0.04)	(0.11)	(0.05)	(0.04)
Constant	0.671***	1.134***	0.689***	0.857***	0.727***
	(0.07)	(0.18)	(0.16)	(0.14)	(0.11)
R^2	0.290	0.490	0.136	0.367	0.338
Number of firms	1770	444	507	1148	3869
Wu–Hausman *F* statistic	39.45***	943.47***	3.89*	9.80***	3.71***
Sargan statistic	1.59	0.05	1.47	0.29	0.54
Sargan *p* value	0.21	0.83	0.23	0.59	0.46

Note: Results display the second-stage instrumental variable two-stage least-squares (IV-2SLS) estimations on the effect of the sophistication of informational technologies and systems (*DIG-LEVEL*) on the eco-innovation (*EI*) and firm growth (*GROWTH*) relationship. We provide the first-stage regression findings in Table A4. We use two-stage models to control selection bias and use the IV-2SLS estimators. Columns 1–4 present the results using Equation (2) when *DIG-LEVEL* equals 1–4, respectively. Column 5 uses *DIG-LEVEL* as a single ordinal variable with values from 1 to 4. Standard errors clustered at the industry level in parentheses.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

TABLE 4 | The effect of internal digital capabilities.

Dependent variable: ***GROWTH***	**(1) *BASELINE***	**(2) *INT-BARR ONLY***	**(3) *EXT-BARR ONLY***	**(4) *BOTH-BARR***	**(5) *Interaction INT-BARR ONLY***	**(6) *Interaction EXT-BARR ONLY***	**(7) *Interaction BOTH-BARR***
EI	0.122***	0.109	0.444**	−0.016	0.110*	0.093	0.142**
	(0.02)	(0.15)	(0.18)	(0.04)	(0.06)	(0.06)	(0.06)
INT-BARR					−0.038		
					(0.02)		
*EI*INT-BARR*					0.047		
					(0.07)		
EXT-BARR						−0.024	
						(0.03)	
*EI*EXT-BARR*						0.134**	
						(0.07)	
BOTH-BARR							0.039
							(0.03)
*EI*BOTH-BARR*							−0.069
							(0.06)
SIZE (t − 3)	−0.427***	−0.530***	−0.403***	−0.432***	−0.427***	−0.426***	−0.427***
	(0.03)	(0.04)	(0.04)	(0.04)	(0.01)	(0.01)	(0.01)
AGE	−0.000	−0.001	0.001	−0.001	−0.000	−0.000	−0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
STRAT-FOCUS	0.038***	0.052***	0.017	0.061***	0.038***	0.039***	0.037***
	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
GOODS	0.016*	0.062*	0.003	0.028**	0.016	0.016	0.016
	(0.01)	(0.04)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
PATENTEE	0.018	−0.094	−0.076	0.035	0.018	0.018	0.019
	(0.03)	(0.09)	(0.07)	(0.03)	(0.02)	(0.02)	(0.02)
EXPORTER	0.036***	0.056**	0.041**	0.035*	0.036***	0.037***	0.036***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)

(Continues)

TABLE 4 | (Continued)

Dependent variable: ***GROWTH***	**(1)** ***BASELINE***	**(2)** ***INT-BARR ONLY***	**(3)** ***EXT-BARR ONLY***	**(4)** ***BOTH-BARR***	**(5)** ***Interaction INT-BARR ONLY***	**(6)** ***Interaction EXT-BARR ONLY***	**(7)** ***Interaction BOTH-BARR***
OWNED > 1	0.073***	0.094**	0.041*	0.075***	0.073***	0.072***	0.073***
	(0.01)	(0.04)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)
EQUITY-OWNED	0.049	0.031	0.025	0.069	0.050	0.049	0.049
	(0.03)	(0.08)	(0.07)	(0.09)	(0.04)	(0.04)	(0.04)
FAMILY-OWNED	−0.039**	−0.038	−0.065*	−0.004	−0.039***	−0.039***	−0.039***
	(0.02)	(0.04)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)
REGION-BUS-ENV = 2	0.049*	−0.001	0.025	0.088	0.050	0.047	0.050
	(0.03)	(0.08)	(0.08)	(0.06)	(0.03)	(0.03)	(0.03)
REGION-BUS-ENV = 3	0.117***	0.159**	0.071	0.146***	0.118***	0.116***	0.119***
	(0.03)	(0.07)	(0.06)	(0.05)	(0.03)	(0.03)	(0.03)
REGION-BUS-ENV = 4	0.145***	0.212***	0.151**	0.184***	0.146***	0.144***	0.147***
	(0.03)	(0.07)	(0.06)	(0.05)	(0.03)	(0.03)	(0.03)
Constant	0.592***	0.678***	0.597***	0.863***	0.600***	0.595***	0.582***
	(0.06)	(0.15)	(0.12)	(0.09)	(0.08)	(0.08)	(0.09)
R^2	0.302	0.409	0.049	0.387	0.324	0.325	0.324
Number of firms	5015	957	869	1206	5015	5015	5015
Wu–Hausman F statistic	13.36***	5.53***	17.34***	31.76***	4.86***	3.67***	7.20***
Sargan statistic	0.17	1.08	0.11	0.63	0.12	0.17	0.13
Sargan p value	0.69	0.30	0.74	0.43	0.73	0.68	0.72

Note: This table shows the findings of the second-stage instrumental variable two-stage least-squares (IV-2SLS) estimations on whether microfirms' internal digital capabilities help them to translate eco-innovation efforts to growth performance. We provide the first-stage regression findings in Table A5. We use two-stage models to control selection bias and use the IV-2SLS estimators. Column 1 includes our baseline estimations where we include all observations in the sample. Columns 2–4 present the estimations for *INT-BARR ONLY* firms, *EXT-BARR ONLY* firms and *BOTH-BARR* firms, respectively. Columns 5–7 present the interaction analyses findings. Standard errors clustered at the industry level in parentheses.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

the coefficient of *EI* is significant for *DIG-LEVEL* = 3 at the 10% level, and the impact is most significant (1%) at the highest digitalisation level, *DIG-LEVEL* = 4, where firms adopt advanced IST. In other words, eco-innovations of microfirms can only boost firm growth when coupled with the adoption of advanced IST, as opposed to basic IST (Somohano-Rodríguez et al. 2020). Column 5 in Table 3 presents the findings when we use an interaction term (*EI*DIGIT-LEVEL*) instead of split samples. *DIG-LEVEL* is used as a single ordinal variable with values from 1 to 4. The coefficient of the interaction *EI*DIG-LEVEL* is positive and significant, confirming our previous findings.

4.3 | The Effects of Digital Resources and Capabilities

Finally, we test whether microfirms' internal digital resources and capabilities help them to translate eco-innovations into growth (H3). Table 4 presents our findings on the second-stage regressions, while the first-stage regression findings are displayed in Table A5.

Column 1 presents our baseline estimations where we include all observations in the sample. The positive and significant coefficient of the *EI* variable reveals the positive influence of eco-innovation efforts on firms' growth performance. Columns 2–4 present the estimations for microfirms with only internal barriers to digitalisation (*INT-BARR ONLY*), only external barriers (*EXT-BARR ONLY*) and both types of barriers (*BOTH-BARR*).

Column 2 demonstrates that the positive influence of eco-innovations on firm growth vanishes when firms face only internal barriers to digitalisation—specifically, when they lack unique resources and capabilities essential for ITOT. However, when firms experience only external barriers, the positive and significant influence of eco-innovation on growth remains (Column 3). This shows that when firms face external barriers alone (e.g., access to finance or regulatory obstacles), they can still leverage their existing internal resources and capabilities to overcome these challenges. External pressures, such as regulatory or competitive constraints, may even encourage enterprises to adopt cleaner processes or manufacture products that meet eco-conscious consumer demand, resulting in a competitive advantage and growth. Column 4 shows the regression results for firms that are facing both internal and external barriers to digitalisation, and the impact of eco-innovation on growth is still insignificant. Therefore, we conclude that the positive relationship between eco-innovation and firm growth is contingent on the presence of internal digital resources and capabilities. Our finding confirms H3, aligning with literature that documents the importance of digital resources and capabilities for the decoupling of economic growth and climate change through enabling eco-innovations (Cai et al. 2013; Faucheux and Nicolaï 2011). Columns 5–7 in Table 4 display the findings when we use interaction terms instead of split samples. Column 5 includes the direct effects of *EI* and *INT-BARR* (=1 for firms facing only internal barriers, 0 = otherwise) and the interaction term *EI*INT-BARR*. Meanwhile, Column 6 includes the direct effects of *EI* and *EXT-BARR* (=1 for firms facing only external barriers, 0 = otherwise) and the interaction term *EI*EXT-BARR*.

TABLE 5 | Firms implementing all three strategies.

	(1) First stage	(2) Second stage
SUSTAINABLE-STRAT	0.219***	
	(0.07)	
INCOMPAT-BUSINESS	−0.089	
	(0.05)	
EI		0.299**
		(0.17)
SIZE (t − 3)	0.030	−0.508***
	(0.04)	(0.05)
AGE	−0.001	0.000
	(0.00)	(0.00)
STRAT-FOC	0.160*	−0.030
	(0.07)	(0.05)
GOODS	0.031	−0.016
	(0.05)	(0.04)
PATENTEE	0.068	0.005
	(0.09)	(0.03)
EXPORTER	0.109**	−0.002
	(0.05)	(0.05)
OWNED > 1	0.044	0.029
	(0.05)	(0.03)
EQUITY-OWNED	0.016	0.171
	(0.09)	(0.15)
FAMILY-OWNED	0.069	−0.077**
	(0.10)	(0.04)
REGION-BUS-ENV = 2	−0.232	−0.139
	(0.23)	(0.14)
REGION-BUS-ENV = 3	−0.155	−0.048
	(0.26)	(0.13)
REGION-BUS-ENV = 4	−0.082	0.025
	(0.28)	(0.13)
Constant	0.153	1.153***
	(0.25)	(0.19)
R^2	0.285	0.390
Number of firms	393	393

Note: Results display the findings for the firms that implement all three strategies together, that is, for firms that simultaneously set a digitalisation strategy, adopt advanced IST and have strong internal digital resources and capabilities. We use two-stage models to control selection bias and use the instrumental variable two-stage least-squares (IV-2SLS) estimators. Columns 1 and 2 display the first- and second-stage regressions. Standard errors clustered at the industry level in parentheses.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

Finally, Column 7 incorporates the direct effects of *EI* and *BOTH-BARR* (=1 for firms facing both internal and external barriers, 0=otherwise) and the interaction term *EI*BOTH-BARR*. The coefficients of the interaction is positive and significant only for the *EI*EXT-BARR* variable, that is, when only external barriers are present but internal barriers are not present. The coefficient of interaction terms are insignificant for the cases when internal barriers are present, that is, *EI*INT-BARR* and *EI*BOTH-BARR*. This confirms our previous findings that the positive relationship between eco-innovation and firm growth is contingent on the presence of internal digital resources and capabilities.

4.4 | Further Analyses

We next compare the relative effects of (i) setting a digitalisation strategy, (ii) advanced IST adoption and (iii) strong digital resources and capabilities on raising employment growth. For this purpose, we examine the magnitude of the coefficients of the eco-innovation variable in the regressions in Table 2 (Column 2), Table 3 (Column 4) and Table 4 (Column 1). We observe that the most effective strategy in terms of raising employment growth is the implementation of digitalisation strategies, followed by advanced IST adoption, and then strong digital resources and capabilities.

Moreover, we examine firms that implement all three elements (i, ii and iii) together, that is, for firms that simultaneously set a digitalisation strategy, adopt advanced IST and have strong internal digital resources and capabilities. We display our findings in Table 5. These firms, although fewer in number, tend to show stronger growth effects. Due to the diversity in firm capabilities and resources, it is not easy for microfirms to implement all three strategies simultaneously. Thus, while the combined implementation of i, ii and iii may yield the highest growth, it might not be straightforward to control across samples given the heterogeneity among firms. Each element contributes positively to employment growth, as supported by our hypotheses, and our further analyses emphasise the importance of each strategy in fostering firm growth.

5 | Conclusions

This paper shows that firms' ITOT plays an important role in fostering the sustainability-led growth of microfirms. The findings reveal important synergies between microfirms' eco-innovation and ITOT efforts/investments, extending and confirming insights from previous information systems literature (Hanelt et al. 2017; Elliot and Webster 2017). In particular, we show that ITOT conceptualised as (a) having a formal digitalisation strategy at the firm level, (b) adopting advanced IST (instead of basic IST) and (c) building internal digital resources and capabilities, increases the likelihood of firms experiencing growth as a result of their eco-innovation efforts.

Theoretically, we contribute to literature in three ways. First, the study operates at the intersection of the sustainability and information systems literatures (Bag et al. 2020; Benitez-Amado and Walczuch 2012; Brozzi et al. 2020; Gurbaxani and Dunkle 2019; Hanelt et al. 2017). We contribute to the information systems literature that emphasises that ITOT plays a crucial role in boosting firm performance, driving innovation, productivity, profitability, growth and increasing customer satisfaction and loyalty (Hanelt et al. 2017; Wessel et al. 2021), by providing evidence that ITOT can also enhance firms' environmental sustainability and lead to growth.

Second, the paper extends the sustainability literature as it enhances our understanding of firm growth in the current complex socio-economic contexts as pressures mount on firms to evolve their businesses for climate change and digitalisation (Colombelli et al. 2021; Yi and Demirel 2023). In support of growing policy initiatives to embrace the twin digital and ecological transformations (European Commission 2021), we argue that ITOT has an important role to play as an enabler of eco-innovation-driven growth.

Third, our results are particularly promising for the joint diffusion of environmental practices and ITOT in a large, yet often-overlooked section of the economy: the microfirms. Microfirms, with their limited resources, are typically viewed as laggards with respect to innovation, including environmental and digital innovations (Leonidou et al. 2017). Yet, our findings contribute to recent evidence highlighting the higher-than-expected innovation potential of microfirms with a specific emphasis on their eco-innovation and digital innovation activities (Bidan et al. 2012; Farè 2022; Moeuf et al. 2020).

Our results have important policy implications. Policy interventions are essential to ensure that markets and value chains are redesigned to prioritise green and digital innovations of all firms, but especially smaller ones with limited access to financial and other resources. As supply and demand policies are growingly needed and adopted to open up and scale new markets for green products and services in the transition towards net-zero pollution, microfirms should be given careful consideration to engage them effectively in the transition. We recommend complementing environmental policies with digitalisation policies in order to leverage the synergistic benefits in twin (digital and ecological) transitions.

The study also presents managerial recommendations for microfirms, which constitute a significant segment of the economy globally. First, we suggest that owners/managers with a green vision should prioritise ITOT and do so with a formalised strategic plan. Such a strategic approach towards digitalisation can enable microfirms to overcome myopia, which is a natural outcome of resource limitations and a major barrier to sustainability.

Second, microfirms would benefit from adopting the most advanced IST tools and artefacts possible when implementing ITOT. Basic IST implementation is unlikely to generate the necessary synergies with the firm's sustainability investments and, hence, offer limited opportunities for a sustainability-led growth pathway. To overcome the resource limitations when implementing ITOT and sustainability jointly, microfirms can focus on digital products and process innovations with clear environmental outcomes and objectives, such as energy and resource savings. Examples of such innovations include digital energy efficiency products and platforms, such as smart energy monitoring systems or automated manufacturing processes, which leverage digital capabilities to provide energy efficiencies and resource savings.

Finally, we recommend that owners/managers in microfirms do not singularly focus on environmental innovations but have a strong focus on the broader digital resources and capabilities in their firms. Our study reveals that microfirms need to build strong internal digital capabilities (i.e., routines, processes and training) to grow out of green investments.

The study also presents limitations, mostly related to the nature of the available dataset. While fulfilling an important gap in the sustainability and information systems literatures by focusing on microfirms, the findings only apply to microfirms. An analysis across the full firm size range would help to establish the precise impact of ITOT as a contingency factor for the relationship between eco-innovation and firm growth. Second, the cross-sectional nature of the dataset can limit the precision of econometric estimations. Third, the variables are based on the self-reported perceptions of respondents, which are potentially subject to respondent bias. Fourth, the analysis does not include certain eco-innovation determinants as per the literature, such as public policy variables, technology-push variables and market-pull variables as well as broader technological determinants of eco-innovation (De Marchi 2012; Kesidou and Demirel 2012; Del Río et al. 2015; Jové-Llopis and Segarra-Blasco 2018; Pinkse et al. 2024). While our analysis includes country and industry fixed effects to control for institutional and industry-specific factors, and we conduct endogeneity tests to ensure robustness, we acknowledge that the absence of detailed R&D and collaboration data, particularly for microfirms, may introduce some bias. Future research should aim to incorporate these additional determinants to provide a more comprehensive analysis. Future work can also examine the relationships considered in this paper using panel datasets to gain further insights into the role of ITOT in sustainability-led growth over time.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data used in this study are available and downloadable under Creative Commons Attribution 4.0 International on http://data.europa.eu/88u/dataset/s2244_486_eng.

Endnotes

[1] Green growth is defined as 'fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies' (OECD 2011, 11).

[2] The term 'eco-innovation' is often used interchangeably with environmental, green or sustainable innovation terms to emphasize the environmentally benign or climate neutral nature of these innovations. Because subtle contextual differences exist between these innovation terms, we use the eco-innovation term that has a broad definition to include 'all forms of innovations that reduce environmental impact … throughout the lifecycle of related activities' (OECD 2011, 29).

[3] Similarly to the case of digitalisation, the sustainability performance of microfirms, measured in energy efficiency, environmental innovations and environmental impact measurement, lags behind large firms (OECD 2021). These shortcomings stem from the liabilities of newness and smallness in microfirms, which in turn exacerbate the uncertainty regarding the returns on investments, triggering short-term market perspectives (Coad 2018; Jibril et al. 2024). As a result, microfirms underinvest in innovations related to both sustainability and digitalisation.

[4] Because the significant impact of COVID-19 on employment was more prominent after May 2020, the COVID-19 crisis does not affect our findings on employment growth.

[5] We use Q24 in the survey to generate our main eco-innovation proxy, *EI*, which reveals the eco-innovation intentions of firms. To better distinguish between firms that intend to develop and those that have already successfully introduced these innovations to the market, we also generate an alternative binary eco-innovation variable from Q19. This alternative eco-innovation proxy equals 1 if the firm confirms that they have already introduced an innovation with an environmental benefit, including innovations with an energy or resource efficiency benefit during the past 12 months. Our findings are consistent when we use the alternative specification, and they are available upon request.

[6] The rest of the sample which constitutes 40% corresponds to the ones that face no digitalisation barriers.

[7] The regional business environment measure is based on the perception of the respondent within each firm and thus subject to respondent bias. To mitigate this potential bias, we have included country-fixed effects in our analysis, which control for unobserved heterogeneity at the country level.

[8] We derived the *SUSTAINABLE-STRAT* variable from Question 25 of the survey, which asks: 'Do you have a strategy or action plan to become a sustainable enterprise, i.e., combine long-term success and profitability with a positive impact on society and the environment?' Our binary variable *SUSTAINABLE-STRAT* is set to one when firms respond with 'Yes, and it has already been implemented' or 'Yes, and it is in the process of being implemented'. For robustness, we also created an alternative version of this variable, where *SUSTAINABLE-STRAT* equals one only for firms that selected 'Yes, and it has already been implemented', excluding those in the process of implementation. Our results remain robust with this alternative variable specification.

[9] The estimated coefficients for our instruments in the first stage regressions are in line with expectations. The coefficient of *SUSTAINABLE-STRAT* is positive and significant at the 1% level both in Columns 1 and 3, revealing that microfirms with a strategy to become sustainable enterprises are more likely to conduct eco-innovations. Besides, the coefficient of *INCOMPAT-BUSINESS* is negative and significant, showing that microfirms that experience sustainability barriers in terms of having incompatible business models are less likely to adopt eco-innovations. We present the validity and reliability test statistics at the bottom of Table 2. Wu–Hausman *F* statistics are significant at the 1% level, rejecting the null hypothesis that our eco-innovation variable, *EI*, is exogenous. First-stage *F* statistics are significant at the 1% level, rejecting the null hypothesis that the instruments are weak. Sargan statistics are insignificant, suggesting that the instruments are valid, and our model is correctly specified.

[10] Our observed 0.28% increase in growth, translating to 17% of the average firm growth, aligns with findings in the literature, emphasizing the importance of such an effect in the context of microfirms. Microfirms typically operate with limited resources and smaller scales. As documented by Coad and Hölzl (2012) and Colombelli

et al. (2021), even small percentage increases in growth can be substantial in resource-constrained environments typical of microfirms.

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Appendix A

TABLE A1 | Country and industry breakdown.

Panel A: Country Breakdown

Country	Number of firms	% of total	Country	Number of firms	% of total
Austria	161	3.21	Kosovo	84	1.67
Belgium	167	3.33	Latvia	142	2.83
Bosnia and Herzegovina	77	1.54	Lithuania	148	2.95
Brazil	112	2.23	Luxembourg	51	1.02
Bulgaria	130	2.59	Macedonia	68	1.36
Canada	164	3.27	Malta	46	0.92
Croatia	170	3.39	Netherlands	164	3.27
Cyprus	52	1.04	Norway	132	2.63
Czech Republic	121	2.41	Poland	126	2.51
Denmark	142	2.83	Portugal	191	3.81
Estonia	119	2.37	Romania	191	3.81
Finland	146	2.91	Serbia	64	1.28
France	188	3.75	Slovakia	121	2.41
Germany	169	3.37	Slovenia	169	3.37
Greece	170	3.39	Spain	152	3.03
Hungary	134	2.67	Sweden	165	3.29
Iceland	55	1.10	Turkey	90	1.79
Ireland	144	2.87	United Kingdom	144	2.87
Italy	103	2.05	USA	154	3.07
Japan	89	1.77	Total	5015	100

Panel B: Industry breakdown

NACE industries	Number of firms	% of total
B—Mining and quarrying	23	0.5%
C—Manufacturing	739	14.7%
D—Electricity, gas, steam and air conditioning supply	21	0.4%
E—Water supply, sewerage, waste management and remediation activities	28	0.6%
F—Construction	485	9.7%
G—Wholesale and retail trade, repair of motor vehicles and motorcycles	1713	34.2%
H—Transporting and storage	248	4.9%
I—Accommodation and food service activities	233	4.6%
J—Information and communication	218	4.3%
K—Financial and insurance activities	106	2.1%
L—Real estate activities	128	2.6%
M—Professional, scientific and technical activities	595	11.9%
N—Administrative and support service activities	203	4.0%
P—Education	81	1.6%

(Continues)

TABLE A1 | (Continued)

Panel B: Industry breakdown		
NACE industries	Number of firms	% of total
Q—Human health and social work activities	106	2.1%
R—Arts, entertainment and recreation	88	1.8%
Grand total	5015	

Note: This table displays the country and industry breakdown of the sample. Panel A lists the 39 countries where firms are located and the corresponding number of firms. Panel B displays the industry breakdown of the sample according to NACE standards.

TABLE A2 | Description of the variables.

Variables	Description
Dependent variable	
Firm growth (*GROWTH*) (%)	Growth in the number of employees, excluding the owners, measured as a percentage between 2020 and 2017. It is calculated as Ln (Number of employees in 2020) – Ln (Number of employees in 2017).
Eco-innovation variables	
Eco-innovation (*EI*)	Takes the value of 1 if the enterprise is actively taking actions on developing sustainable products or services in terms of environmental and social sustainability and 0 otherwise. We use Q24 in the survey to generate our main eco-innovation proxy, *EI*. We generate *EI* equals 1 when the response is yes to 'Developing sustainable products or services', 0 otherwise.
Digitalisation variables	
Digital transformation strategy (*DIGIT-STRATEGY*)	Equals 1 if the enterprise plans to grow, either in terms of employment or turnover, as a result of increased digitalisation, 0 otherwise. We use Question 7A from the survey when we generate the variable *DIGIT-STRATEGY*. Specifically, the question asks, 'In terms of growth either in employment or in turnover, does your enterprise …'. We generate *DIGIT-STRATEGY* equals to one when firms fill out choice five, which is 'Plan to grow as a result of increased digitalisation in your enterprise'.
Digitalisation levels (*DIG-LEVEL*)	It shows the enterprise's approach to digital technologies. It is coded as a categorical variable that is classified into four categories: 1. The enterprise has adopted or is planning to adopt *basic* digital technologies (such as email or a website) but not advanced digital technologies. 2. There is a need to introduce advanced digital technologies but the firm lacks the knowledge, skills or financing. 3. There is a need to adopt advanced digital technologies and the firm is currently considering which to implement. 4. There is a need to adopt *advanced* digital technologies and the firm has already started to implement them. This variable is generated from Survey Question 22. There is, in fact, one more level, numbered 5, that states, 'Your enterprise does not need to adopt any digital technologies'. We have not taken this level into account because its meaning might be ambiguous. It might not very clearly indicate whether the enterprise has no need to adopt any digital technologies because it has already adopted all of them or whether the enterprise has not even considered adopting any.
Internal barriers to digitalisation only (*INT-BARR ONLY*)	It takes the value of 1 for firms that are only facing internal barriers to digitalisation and not facing any external barriers, 0 otherwise. Firms are facing internal barriers if any of the following is a barrier to digitalisation: 1. lack of skills, including managerial skills; 2. lack of financial resources; 3. internal resistance to change. We use Question 21 from the survey when we generate the variables that account for internal barriers to digitalisation.

(Continues)

TABLE A2 | (Continued)

Variables	Description
External barriers to digitalisation only (*EXT-BARR ONLY*)	Takes the value of 1 if firms are facing only external barriers to digitalisation, 0 otherwise. Firms are accepted as facing an external barrier if any of the following is a barrier to digitalisation: 1. regulatory obstacles; 2. lack of information technology infrastructure, such as high-speed internet connection; 3. IT security issues; 4. uncertainty about future digital standards. We use Question 21 from the survey when we generate the variables that account for external barriers to digitalisation.
Both barriers to digitalisation (*BOTH-BARR*)	Takes the value of 1 if firms are facing both internal and external barriers to digitalisation, 0 otherwise. We use Question 21 from the survey when we generate the variables that account for both internal and external barriers to digitalisation.
Firm characteristics	
Firm size (*SIZE* $(t-3)$)	The natural logarithm of the number of employees in 2017. Since the survey was conducted in 2020, the reported number of employees in 2017 is taken as $t-3$.
Firm age (*AGE*)	The number of years since establishment.
Strategy focused (*STRAT-FOCUS*)	Takes the value of 1 if, in terms of growth either in employment or in turnover, the enterprise has a strategic growth plan, 0 otherwise.
Goods (*GOODS*)	A dummy variable indicates that the firm mainly provides goods. Our comparison category is services, that is, the rest of the firms mainly provide services.
Patentee (*PATENTEE*)	Takes the value of 1 if the firm has a patent or patent application, 0 otherwise.
Exporter (*EXPORTER*)	Takes the value of 1 if the enterprise had exported goods or services to international markets in 2019, 0 otherwise.
Ownership characteristics	
Owned more than 1 (*OWNED* > *1*)	Equals 1 if the enterprise is owned by more than one person, 0 otherwise.
Equity ownership (*EQUITY-OWNED*)	Equals 1 if the enterprise is co-owned by venture capital firms or by business angels, 0 otherwise.
Family ownership (*FAMILY-OWNED*)	Equals 1 if the enterprise is predominantly family owned, 0 otherwise.
Country characteristics	
Regional business environment (*REGION-BUS-ENV*)	It shows the rating of the overall strength and performance of the regional business environment in their corresponding countries as perceived by the respondents. It is coded as a categorical variable that is classified into four categories: (1) very poor, (2) fairly poor, (3) fairly good and (4) very good.
Instrumental variables	
Sustainable enterprise strategy (*SUSTAINABLE-STRAT*)	Equals 1 if the enterprise has a strategy or action plan to become a sustainable enterprise, that is, combine long-term success and profitability with a positive impact on society and the environment, 0 otherwise. It takes the value of 1 for the enterprises that either have already implemented such a strategy or are in the process of implementing it. We use Question 25 from the survey when we generate *SUSTAINABLE-STRAT*. Specifically, the question asks, 'Do you have a strategy or action plan to become a sustainable enterprise, i.e., combine long-term success and profitability with a positive impact on society and the environment?'. We generate our binary variable *SUSTAINABLE-STRAT* equals to one when firms fill out choices one and two, which are 'Yes, and it has already been implemented' and 'Yes, and it is in the process of being implemented', respectively.
Incompatible business model (*INCOMPAT-BUSINESS*)	Equals 1 if the enterprise is facing a sustainability barrier in terms of having an incompatible business model which prevents the firm from becoming sustainable, 0 otherwise.

Note: This table shows the list of variables that are used in the regressions and their brief descriptions for our sample of 5015 microfirms from 39 countries for the year 2020.

TABLE A3 | Correlation table.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) *GROWTH*	1									
(2) *EI*	−0.005	1								
(3) *DIGIT-STRATEGY*	0.0089	0.1786*	1							
(4) *DIG-LEVEL*	0.0434*	0.1392*	0.2162*	1						
(5) *INT-BARR ONLY*	−0.0321*	−0.006	−0.0072	0.003	1					
(6) *EXT-BARR ONLY*	0.0441*	0.021	0.0418*	0.028	−0.2223*	1				
(7) *BOTH-BARR*	−0.0031	0.1281*	0.1918*	0.1108*	−0.2733*	−0.2576*	1			
(8) *SIZE (t* − *3)*	−0.5243*	0.0075	0.0315*	0.0346*	0.0073	−0.0273	0.0459*	1		
(9) *AGE*	−0.0850*	−0.0033	0.0137	0.0025	−0.01	0.0183	0.0392*	0.1567*	1	
(10) *STRAT-FOCUS*	0.0580*	0.2194*	0.2822*	0.1883*	−0.0198	0.0229	0.1472*	0.0272	−0.0218	1
(11) *GOODS*	0.009	0.0434*	0.0400*	0.013	0.0164	0.0029	0.0202	0.0427*	0.1131*	0.0703*
(12) *PATENTEE*	0.0225	0.1449*	0.1341*	0.0965*	−0.0251	0.0156	0.0797*	0.0366*	−0.015	0.1756*
(13) *EXPORTER*	0.0412*	0.0472*	0.0392*	0.1051*	−0.0069	0.0081	0.0021	0.0425*	−0.0362*	0.0634*
(14) *OWNED* > *1*	0.0729*	0.0666*	0.0581*	0.0719*	−0.0076	0.0196	0.0243	0.0364*	0.0017	0.0685*
(15) *EQUITY-OWNED*	0.0267	0.0619*	0.0486*	0.0342*	−0.0035	0.0064	0.0158	0.0108	−0.0146	0.0638*
(16) *FAMILY-OWNED*	0.0057	0.1130*	0.1021*	0.0502*	−0.0249	0.0277*	0.0872*	0.0131	0.1258*	0.0996*
(17) *REGION-BUS-ENV*	0.0892*	0.0664*	0.0674*	0.022	−0.0254	0.0345*	−0.0427*	−0.0252	0.0249	0.0687*
(18) *SUSTAINABLE-STRAT*	0.0226	0.1982*	0.0626*	0.0347*	−0.0211	0.0469*	−0.0152	0.0217	0.0026	0.1641*
(19) *INCOMPAT-BUSINESS*	−0.0018	−0.0521*	0.0515*	0.0354*	−0.0376*	−0.0149	0.1132*	−0.0015	0.0077	0.0132

Note: This table displays the correlation matrix for the variables that are used in our analysis.
*Significance at 0.05.

TABLE A3 | Correlation table (continued).

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(11) *GOODS*	1								
(12) *PATENTEE*	0.0791*	1							
(13) *EXPORTER*	0.1464*	0.0983*	1						
(14) *OWNED > 1*	0.0576*	0.0303*	0.0734*	1					
(15) *EQUITY-OWNED*	0.0300*	0.0663*	0.0460*	0.0917*	1				
(16) *FAMILY-OWNED*	0.0930*	0.0557*	0.012	0.3418*	0.0598*	1			
(17) *REGION-BUS-ENV*	−0.0321*	0.0336*	−0.02	−0.0111	−0.0018	0.0159	1		
(18) *SUSTAINABLE-STRAT*	0.0182	0.0965*	0.0299*	−0.0227	0.0049	0.003	0.0346*	1	
(19) *INCOMPAT-BUSINESS*	−0.0103	0.0198	−0.0426*	0.0237	−0.0013	0.0409*	0.0528*	−0.1813*	1

Note: This table displays the correlation matrix for the variables that are used in our analysis.
*Significance at 0.05.

TABLE A4 | First-stage regressions on the sophistication of informational technologies and systems.

Dependent variable: *EI*	(1) *DIG-LEVEL* = 1	(2) *DIG-LEVEL* = 2	(3) *DIG-LEVEL* = 3	(4) *DIG-LEVEL* = 4	(5) *Interaction*
SUSTAINABLE-STRAT	0.160***	0.105*	0.079*	0.191***	0.154***
	(0.03)	(0.05)	(0.04)	(0.03)	(0.02)
INCOMPAT-BUSINESS	−0.072**	−0.035	−0.123***	−0.065***	−0.076***
	(0.03)	(0.08)	(0.04)	(0.02)	(0.01)
SIZE ($t-3$)	−0.021	0.022	0.001	0.003	0.001
	(0.02)	(0.04)	(0.03)	(0.03)	(0.01)
AGE	−0.000	−0.003**	0.001	−0.001	−0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
STRAT-FOC	0.151***	0.018	0.162***	0.119***	0.119***
	(0.02)	(0.04)	(0.05)	(0.03)	(0.01)
GOODS	0.037	0.002	−0.080	0.042	0.013
	(0.03)	(0.04)	(0.09)	(0.04)	(0.02)
PATENTEE	0.140**	0.050	0.117	0.134**	0.143***
	(0.05)	(0.09)	(0.09)	(0.05)	(0.03)
EXPORTER	0.040*	0.123***	0.003	0.046	0.037*
	(0.02)	(0.03)	(0.05)	(0.04)	(0.02)
OWNED > 1	−0.003	−0.060	0.052	0.022	0.008
	(0.02)	(0.04)	(0.04)	(0.01)	(0.02)
EQUITY-OWNED	0.243**	0.080	−0.100	0.039	0.117**
	(0.10)	(0.31)	(0.16)	(0.07)	(0.05)
FAMILY-OWNED	0.031**	0.234**	0.083*	0.040	0.059**
	(0.01)	(0.09)	(0.04)	(0.05)	(0.02)
REGION-BUS-ENV = 2	0.018	−0.106	0.234***	−0.073	−0.025
	(0.05)	(0.08)	(0.05)	(0.07)	(0.03)
REGION-BUS-ENV = 3	0.013	−0.148**	0.224***	−0.057	−0.016
	(0.05)	(0.06)	(0.02)	(0.08)	(0.02)
REGION-BUS-ENV = 4	0.036	−0.170*	0.309***	0.010	0.015
	(0.06)	(0.09)	(0.05)	(0.11)	(0.03)
Constant	0.399***	1.019***	−0.139	−0.005	0.090
	(0.10)	(0.17)	(0.19)	(0.18)	(0.07)
R^2	0.187	0.243	0.283	0.221	0.161
Number of firms	1772	445	507	1150	5024
First-stage *F* statistic	18.29***	2.08***	6.55***	33.24***	14.15***

Note: This table shows the findings of the first-stage instrumental variable two-stage least-squares (IV-2SLS) estimations on the effect of the adoption of advanced digital technologies (*DIG-LEVEL*) on eco-innovation (*EI*). Our dependent variable is *EI* in all specifications. We use two-stage models to control selection bias and use the IV-2SLS estimators. *SUSTAINABLE-STRAT* and *INCOMPAT-BUSINESS* as instrumental variables for *EI* in the first stage of the estimation process. Columns 1–4 present the first-stage results when *DIG-LEVEL* equals 1–4, respectively. Column 5 presents the first-stage findings when we use an interaction term (*EI* * *DIGIT-LEVEL*) in the second stage instead of split samples. One represents the most basic, and four the advanced level of digitalisation capabilities. Standard errors clustered at the industry level in parentheses.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

TABLE A5 | First-stage regressions on the effect of digital capabilities.

	(1) *BASELINE*	(2) *INT-BARR ONLY*	(3) *EXT-BARR ONLY*	(4) *BOTH-BARR*
SUSTAINABLE-STRAT	0.154***	0.139***	0.171***	0.163***
	(0.02)	(0.04)	(0.04)	(0.02)
INCOMPAT-BUSINESS	−0.076***	−0.107*	−0.019	−0.095***
	(0.01)	(0.05)	(0.03)	(0.03)
SIZE (t − 3)	0.001	0.039	0.016	−0.027
	(0.01)	(0.02)	(0.03)	(0.03)
AGE	−0.001	−0.001	−0.000	0.001
	(0.00)	(0.00)	(0.00)	(0.00)
STRAT-FOC	0.119***	0.067**	0.095**	0.104***
	(0.01)	(0.03)	(0.03)	(0.01)
GOODS	0.013	−0.033	0.027	0.002
	(0.02)	(0.05)	(0.04)	(0.03)
PATENTEE	0.143***	0.182***	0.235***	0.124**
	(0.03)	(0.04)	(0.07)	(0.05)
EXPORTER	0.037*	0.056	0.020	0.095***
	(0.02)	(0.04)	(0.04)	(0.02)
OWNED > 1	0.008	0.022	0.037	−0.041
	(0.02)	(0.03)	(0.03)	(0.03)
EQUITY-OWNED	0.117**	−0.085	0.085	0.304***
	(0.05)	(0.11)	(0.11)	(0.08)
FAMILY-OWNED	0.059**	0.067	0.043	0.054
	(0.02)	(0.05)	(0.03)	(0.05)
REGION-BUS-ENV = 2	−0.025	−0.176	0.054	0.075
	(0.03)	(0.11)	(0.08)	(0.09)
REGION-BUS-ENV = 3	−0.016	−0.168	0.023	0.072
	(0.02)	(0.11)	(0.06)	(0.06)
REGION-BUS-ENV = 4	0.015	−0.130	−0.008	0.150*
	(0.03)	(0.10)	(0.07)	(0.07)
Constant	0.090	0.339	0.091	0.097
	(0.07)	(0.23)	(0.13)	(0.08)
R^2	0.161	0.172	0.195	0.180
Number of firms	5024	958	870	1209

Note: This table shows the findings of the first-stage instrumental variable two-stage least-squares (IV-2SLS) estimations on estimations on whether microfirms' internal digital capabilities help them to translate eco-innovation efforts into growth performance. Our dependent variable is eco-innovation (*EI*) in all specifications. We use two-stage models to control selection bias and use the IV-2SLS estimators. *SUSTAINABLE-STRAT* and *INCOMPAT-BUSINESS* as instrumental variables for *EI* in the first stage of the estimation process. Column 1 includes our baseline estimations where we include all observations in the sample. Columns 2–4 present the estimations for *INT-BARR ONLY* firms, *EXT-BARR ONLY* firms and *BOTH-BARR* firms, respectively. We generate the indicator variables *INT-BARR ONLY* for firms facing only internal barriers (but not external barriers) to digitalisation, *EXT-BARR ONLY* for firms facing only external barriers (but not internal barriers) to digitalisation and *BOTH-BARR* for firms that face both internal and external barriers. Standard errors clustered at the industry level in parentheses. Standard errors clustered at the industry level in parentheses.

*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

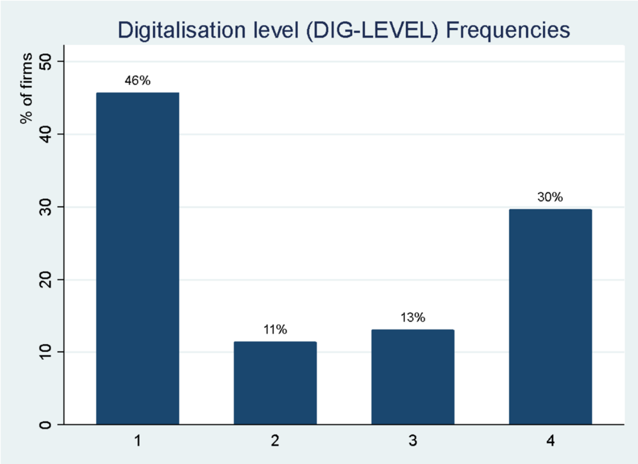

FIGURE A1 | The frequency distribution of digitalisation levels (*DIG-LEVEL*). *DIG-LEVEL* is a categorical variable classified into four levels (1–4). One represents the lowest and the *basic*, and four corresponds to the *advanced* level of digitalisation.