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Essays on Digitalization and Sustainability: An Empirical Investigation of Firms' Adoption of Digital Technologies and Environmental Management Practices

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Looking back at the past few years, I realize that the three ingredients of my personal PhD journey have been doubt, individual perseverance and collective work. Doing a PhD is indeed quite a lonely and unique journey. No PhD path is the same, making it very hard to compare to your peers and assess the real status of your work. The world of science is a world of free questioning where this work is continuously challenged. However, while I believe doubt is a necessary ingredient of science, it can easily impact progress when becoming heavily present. That’s exactly where perseverance comes into play. Perseverance in learning to deal with such doubts without letting them impact your sense of self. Perseverance in trying to better understand the world around you. Finally, perseverance in building the right conditions to make this journey possible, which often means failing at applying for funding, but trying again and again to build the right conditions.

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Besides funding, my PhD journey relied on the following pillars: a supervisor and mentor, other researchers or professors and, finally, a private environment that will always be there whenever the doubts are omnipresent. That's where collective work can take place. On top of the personal quest, doing a PhD is indeed also a collective work that won't be possible without the strong support of colleagues, friends and family. It is time for me now to thank everyone who has been involved in this journey and has supported me throughout the past years.

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Technological progress not accompanied by wisdom is not real progress.

Caroline Pauwels, 2018

EXECUTIVE SUMMARY

This thesis investigates the strategic digital transformation of organizations in the broader context of sustainability imperatives. Concretely, it focuses on the following questions: How are digital technologies such as platforms, artificial intelligence, and Internet of Things adopted today? What are the managerial complements needed to derive sustainable value from such technologies, and how are those adopted themselves? Finally, how do digital transformation and sustainability intersect with each other and how can organizations strategically integrate both?

To tackle these questions, this dissertation is structured as follows: It opens with an introduction consisting of a high-level review of the literature related to strategic management, digital transformation, and sustainability, highlighting the current areas of interest and research gaps.

The first chapter then investigates the specific case of digital platforms and its relationships with strategic management. Leveraging unique data from a cross-industries and cross-continents survey, it first documents two platform positions taken by firms: owner or complementor. In a second step, it assesses the relationship of such positions with value creation, suggesting that the mere decision to make or join a platform is not sufficient to create value unless coupled with integrated value propositions built with external partners.

The second chapter tackles the emerging field of research at the intersection between digital technologies and sustainability specifically. To do so, it documents the adoption of digital technologies (i.e. Internet of Things, cloud computing, immersive technologies, smart robotics and artificial intelligence) and environmental innovation practices (i.e. process, product/service and business model scopes) thanks to a large sample of EU companies. It then explores the

relationships between digital technologies and innovation scopes, shedding light on heterogeneities across technologies and highlighting the transversal role of Internet of Things technologies.

The third and last chapter aims at building theoretical propositions at the intersection between digital transformation and corporate sustainability. Adopting a conceptual and model-based approach illustrated by empirical data, it complements quantitative analyses from the previous chapter by building up an integrative strategic management framework. This guiding conceptual model emphasizes the organizational, operational, and communicational building blocks of such intertwined transformations.

To conclude, this thesis brings empirical findings as well as theoretical contributions to both practice and research. Regarding the empirical findings, it documents the adoption of digital technologies and managerial practices, identifying the determinants of their profusion and highlighting, for example, the role played by firms' size. Furthermore, it shows heterogeneity in the joint presence of digital technologies and specific managerial practices, notably those related to environmental innovation. Building upon these empirical findings and conceptual efforts, this thesis also presents theoretical propositions on the interlinkage between digital transformation, corporate strategy and sustainability. Concretely, it advances organizational and managerial complements needed to derive value from digital technologies today and also suggests an heterogeneous role of such technologies in sustainability transformation.

PART I: INTRODUCTION

1 General introduction

1.1 Context

Our world is the heritage of different waves of industrial developments that have profoundly transformed economic models. Today's digital economy paradigm is based on a key strategic resource: information. Information is defined by Bell (1976) as "the storage, transmission, and processing of data as a basis for all economic and social exchanges." Touraine (1969) and Bell (1976) were among the first to theorize that the post-industrial world would be dominated by intangible production and consumption, based on information digitally processed and disseminated.

Concerning the global economic fabric, the information society led to an increased complexity of interactions and power relations between economic actors. In this context, digital technologies have reshaped organizations' models, giving birth to network-based organizations (e.g. Castells, 1996) where sources of competitive advantage have supposedly shifted from owning specific resources to orchestrating relationships (Alstyne et al., 2016). Moreover, as indicated by Brynjolfsson & McAfee (2014), we are witnessing today a quantitative leap as well as growth in data collection, storage, and processing enabled by the development of cloud-based technologies. These technologies allow for a fast development of data mining and modelling, thereby enabling data-driven organizations.

Algorithms have become increasingly powerful at extracting meaningful information from data, moving from diagnostic potential to predictive or even prescriptive power that can enrich business activities. In recent years, algorithms have been going beyond modelling human reasoning

(Cardon, 2015) and even beyond human understanding by autonomously identifying patterns in data and learning independently. These algorithms compose the field of *machine learning*, one of the key modern branches of artificial intelligence (AI).

The current wave of digitalization is considered by some authors as the fourth industrial revolution, also called Industry 4.0 (e.g. Lasi et al., 2014) or the second machine age (e.g. Brynjolfsson & McAfee, 2014). This consideration distinguishes the current rise of *smart* and *cyber-physical* systems from the computerization of the second half of the 20th century, characterized by the advent of the Internet and home computers. However, there is no scientific consensus on the fact that recent developments can really be considered as a new industrial revolution or disruption. Referring to a conceptual framework developed by "neo-Schumpeterian" or "evolutionary" economists (e.g. Freeman, 1990; Rosenberg, 1994; Perez, 2004), Valenduc & Vendramin (2017) questioned the disruptive character of the current wave of digitalization.

Based on Schumpeter's (1939) early studies on the role of innovation and entrepreneurship in the transition from one economic cycle to the next, which are based on Kondratiev principle of long cycles, evolutionary economists stipulate that the long-term evolution of the economy is based on a succession of techno-economic paradigms of 45 to 50 years. These paradigms are separated by revolutions or great surges, as suggested by Perez (2010) and depicted by Figure 1 below. The techno-economic paradigm does not only concern technological innovation, but also structural changes in the organization of the global economic, alongside a new institutional and social context.

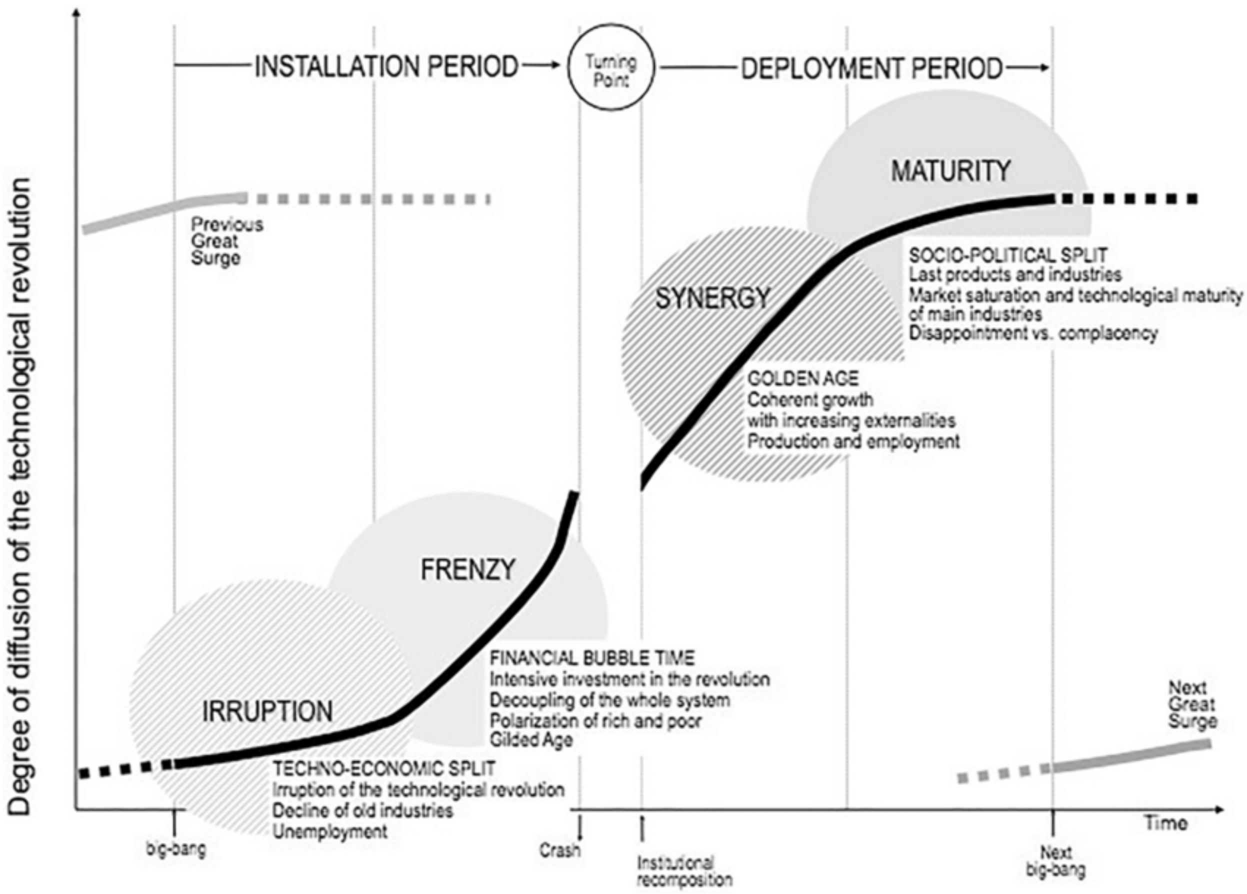


Figure 1. The four phases of a technological revolution's lifecycle (Perez, 2010)

Perez (2010, 2015) provides an analysis of the current technological surge. According to the author, the installation of the current surge started in 1980s with the diffusion of computers and telecommunications networks. The frenzy phase thus concerns the dotcom bubble and the Internet-mania. The end of this frenzy phase is marked by the financial bubbles and crisis of 2008, considered by Perez (2013) as a typical turning point between the installation period of a techno-economic paradigm and the deployment period.

According to this theory, the current paradigm based on digital technologies is in its golden age and therefore includes transformations that are not resulting from a particular set of convergent technologies, but rather from industries innovating in convergent directions with the technology, creating a variety of wealth creation and distribution paths (Valenduc & Vendramin, 2017).

Current digitalization would therefore not be about the irruption of a revolution but rather about pervasive diffusion, use and synergies in digital innovations within the global economy and society. In other words, based on this framework, the period we live in is not the start of a new revolution, but rather the deployment phase of the information society paradigm considered as the fifth great surge. Indeed, according to Perez (2010), the fourth techno-economic paradigm was based on mass production and consumption (Fordist model) and notably enabled by energy technologies (oil and petro-chemistry), automation of manufacturing and the development of transport and communication networks. The third paradigm was based on electrical, mechanical, and metallurgical engineering, while the second one was based on steam engines and the development of railways. The first modern techno-economic paradigm, or first industrial revolution, was based on the textile industry, waterpower, and waterways.

At this stage, it is worth emphasizing that, usually, a new great surge emerges during the maturity phase of the current paradigm. When Valenduc and Vendramin wrote their paper in 2017, generative AI tools were not diffused in the economy and society as they are today. One may therefore ask whether the democratization of current artificial intelligence technologies, such as ChatGPT or Midjourney, is announcing the great surge of a new techno-economic paradigm or is effectively linked to the full deployment of the information society.

Even though it is too early to answer this question and anticipate the direction of such technological innovations, it is relevant to take the broader societal and environmental picture into account in addition to techno-economic developments, to assess whether a new overall paradigm is effectively under way. Industrial evolutions, coupled with scientific breakthrough, have indeed brought important economic and societal benefits, such as extreme poverty reduction (Sachs, 2005) and increased life expectancy (Roser et al., 2013).

However, nuance should be brought into this narrative. Indeed, while technological innovations have enabled these different waves of industrial or economic evolutions, this does not mean overall progress has been achieved. Concerns have indeed risen in terms of social and environmental issues. Regarding environmental issues, the past few centuries have been characterized by a rise of greenhouse gas emissions, leading to global warming and climate change (Calvin et al., 2023). The causal relationship between human activities and climate change is now established in the academic literature (Calvin et al., 2023).

Furthermore, it is worth emphasizing that the attention is placed on carbon emissions as they are responsible for 80% of global warming (Lashof & Ahuja, 1990). However, the health of the planet also depends on nine boundaries including climate change, novel entities, stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biogeochemical flows, freshwater change, land system change and biosphere integrity (Richardson et al., 2023). These boundaries may be interrelated, and crossing a climate boundary can lead to ripple effects on other boundaries. Today, six of the nine planetary boundaries are being crossed, putting the Earth in the high-risk zone (Richardson et al., 2023).

In this context, the Club of Rome has questioned our quest for unlimited growth on a finite planet already in 1972 (Meadows et al., 1972). During the same period, the notion of sustainability and sustainable development as we know it today emerged (Passet, 1979) and was popularized in the early 80s (Purvis et al., 2019). Nowadays, companies face a transformational era marked by the rapid development and proliferation of digital technologies, coupled with sustainability imperatives. This thesis investigates questions at the intersection between these two challenges. Reconciling these two topics is indeed currently high on political agendas. For example, the European Union coined the term *twin transition* (Muench et al., 2022) to refer to the alignment between digital and sustainability transformations. However, as knowledge and policies on these two topics have been developed in silos, there is an urgent need to combine research on such topics to better grasp the relationships between both and better understand elements of tension and synergy at an organizational and practical level. There is a need to shed light on how high-level political strategies translate into organizations and what the managerial implications of such desired transformations are.

Last but not least, it is also worth noting that this question is embedded into two approaches, strategies, or global paradigms that aim at reducing the environmental impacts of economic activities. Santarius et al. (2020) summarize them as follows:

The first approach, called *green growth*, considers that our society needs economic growth and that there is therefore a need to find sustainable modes of production and consumption to decouple economic growth from resource use. The *green growth* or *decoupling* approach, relying mostly on technological innovation, has already been investigated by different authors (e.g. Ekins, 1999), shedding light on the need for sufficient absolute decoupling quickly and deeply enough to achieve sustainability goals (Santarius et al. 2020).

The second approach, called *post growth* or *degrowth* (Parrique, 2019), looks at the drivers of economic growth to identify areas where it can be limited while securing investments in green transformation and well-being. In other words, this approach suggests that we should limit or even reduce aggregate production and consumption itself. Next to techno-economic paradigms, it is crucial in such research to also take the overall context and potential political paradigms that industrial developments are embedded into.

1.2 Purpose

The purpose of this thesis is to reconcile the development of techno-economic paradigms with sustainability imperatives resulting from environmental or societal externalities of recent industrial evolutions. More concretely, it aims at contributing to the emerging and specific field at the nexus between digital transformation and sustainability. At the theoretical level, this work is exploratory and empirical by nature and aims at opening up as well as framing new research areas at the intersection between recent waves of digital transformation and sustainability objectives and practices. Besides the theoretical ambition, this thesis also aims to guide practice by shedding light on emerging complementarities between specific technologies and managerial practices.

Various streams of academic literature have recently emphasized the need to bridge the gap between digital and sustainability issues. As an example, scholars in the Information Systems (IS) discipline (Seidel et al., 2013) argued that the literature largely lacks knowledge about the use of information systems in sustainability transformations in organizations (Elliot, 2011; N. P.

Melville, 2010; Watson et al., 2010). As such, they suggest empirical research as a suitable strategy to develop insights. Papers such as Teece (2011) stated that there is a need for integrated future-oriented studies and for producing research with social value rather than counting publications (vom Brocke et al., 2013).

To address these calls and more specific research gaps that will be detailed in the next chapter, this thesis adopts an exploratory approach that builds up on unique data, thereby offering novel insights on digital transformation and its interactions with sustainability issues at an appropriate conceptual level, such as the technological and managerial levels.

Concretely, it asks first how digital technologies such as platforms, artificial intelligence and Internet of Things are being adopted by firms today. Investigating digital transformation of organizations requires us to improve our knowledge on the current forms of digitalization, therefore asking which technologies are being adopted by firms and what firm-specific (e.g. size) or external factors (e.g. industry) correlate with such adoption.

Then, this thesis investigates the potential managerial complements needed to create sustainable value with such technologies. It looks at managerial practices needed to create financial value, but it also goes beyond such financial indicators to consider the joint presence of technologies and environmental innovation practices. By doing so, it aims at identifying relationships between specific technologies and managerial practices tackling sustainability issues with a focus on environmental ones.

The third and last question driving my research efforts is to better understand how organizations, particularly incumbent firms, can strategically align digital transformation with sustainability. More precisely, it investigates the mechanisms through which these technologies and managerial practices complement each other. By adopting a theory building approach and documenting the phenomenon of digital and sustainability transformation, this thesis opens doors for interdisciplinary research at the intersection between digital transformation and sustainability and offers a first theoretical and conceptual framing of this emerging field.

1.3 Methods and data

The general approach adopted to tackle the questions listed above is exploratory in nature. This research aims to inspire future research as well as practitioners, both industry or political leaders, on the complex relationships between digital and sustainability issues.

Overall, this thesis is characterized by multi- and interdisciplinarity regarding both (1) the topic and (2) the methodology followed. In terms of topics, Santarius et al. (2023) suggest that interdisciplinary knowledge is necessary to understand the relationships between digitalization and sustainability. Therefore, there is a need to integrate knowledge from technical, social, and natural sciences. The authors state that, just as policymakers tackle digitalization and sustainability in separated camps, researchers have also been producing research and knowledge in silos. In this context, and with the ambition to make progress on policies such as the European Digital Green Deal, Santarius et al. (2023) state there is a need to build bridges between disciplines and domain expertise in an interdisciplinary field that would connect digital technologies and their governance within sustainability research.

In terms of methods, the first chapter adopts a deductive approach by testing a set of theoretical hypotheses based on survey data. The second chapter relies on survey data to adopt a rather inductive approach, exploring associations between digital transformation and sustainability practices. By doing so, it builds theoretical propositions on the associations between specific technologies and managerial practices that can be tested in future research on complementarities. The last chapter adopts a theory building approach and develops a process-based and guiding strategic framework at the intersection between digital transformation and corporate sustainability. The understanding of this framework is facilitated by the use of unique qualitative data from large incumbent organizations.

Regarding data, it uses both quantitative and qualitative data by relying on three different datasets. These are unique and recent cross-sectional data collected through surveys and interviews. The future-oriented approach relies on recent datasets to analyze current and emerging phenomenon and provide propositions for its future development. It attempts to identify early practices and relationships, document them and provide strategic guidance on digital transformation and environmental sustainability.

On the one hand, using quantitative data enables the study of the phenomenon on a broader scale across different firms' size, industry, and regions to identify potential patterns. On the other hand, relying on qualitative interview data enables to better understand the mechanisms at play within companies. In both cases, the focus is on the organizational level, and data used are described in detail the dedicated sections of each chapter.

1.4 Structure

To reach its objectives and tackle the research questions emphasized, this thesis will be divided into three parts as described by Figure 2 below.

The remainder of the introduction part provides a mapping of the literatures on digitial transformation, sustainability, and strategic management. Defining the key concepts used throughout the thesis, it highlights the areas of interest and research gaps both in terms of theory and societal questions being raised in the field today.

Then, building upon the general introduction and literature mapping, the second part forms the core of this thesis by investigating digital transformation and its interactions with strategic management and sustainability.

The first chapter does not yet look at the relationship between digital transformation and environmental sustainability specifically but delves first into the question of how the decision to make or join a digital platform influences economic value creation. By doing so, it aims as a first step to shed light on the mechanisms through which firms create economic value in digital environments.

The second and third chapters go beyond the economic perspective by investigating more closely the relationships between digital technologies and corporate sustainability, focusing on the environmental pillar. More concretely, the first of these two chapters explore the joint presence of a set of digital technologies and innovation practices, while the second builds a theoretical and strategic framework integrating digital transformation and corporate sustainability, illustrated by empirical observations.

Finally, the last part aims at concluding this thesis with a discussion regarding the main results and their contribution to theory and practice, highlighting the limitations of this research as well as providing areas for future work in the field.

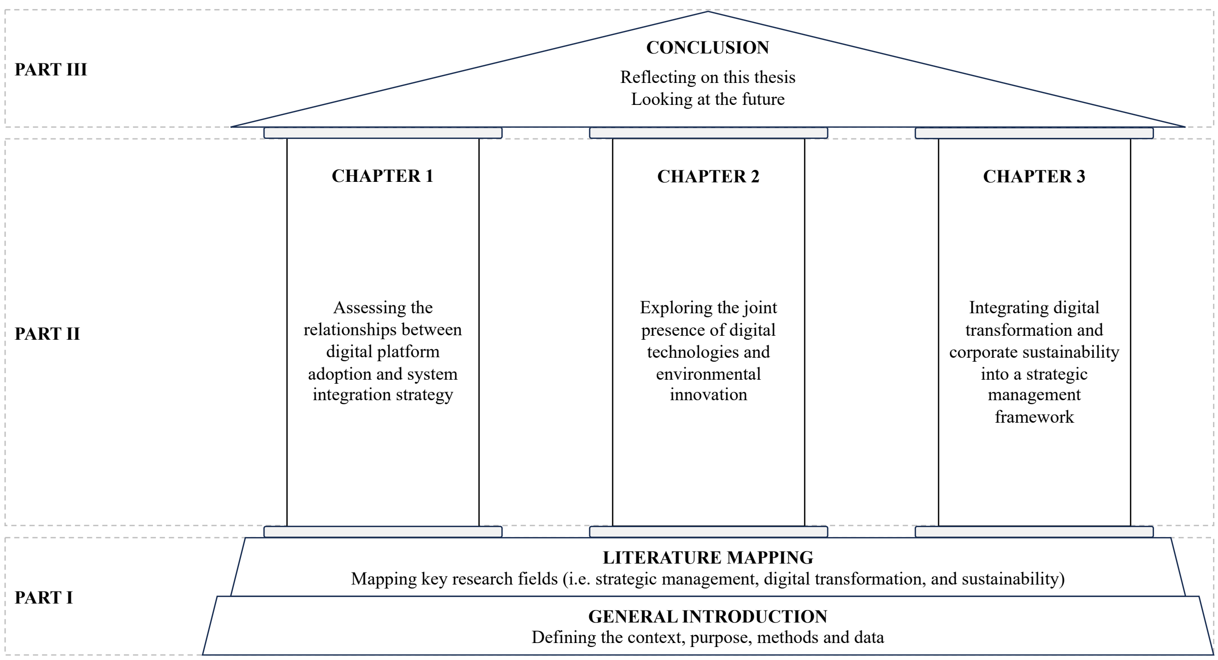


Figure 2. Structure of the thesis

2 Literature mapping

This section introduces the different building blocks of the literature considered in this thesis, thereby providing an overview of the relevant fields of research this research aims at contributing to. These fields are presented as separated components, as if they were isolated. Of course, there are some interactions and overlap between these fields of research. What Figure 3 below aims at showing is that the left-hand side topics of *digital transformation* and the right-hand side topics of *sustainability* have evolved distinctly even though both build knowledge notably upon the management literature or, more specifically, upon the strategic management discipline. To date, there is no systemic and systematic integration of these fields of research. However, as shown by Santarius et al. (2023), aligning these different streams of the literature is necessary if we want to integrate policies and strategies about digital transformation and sustainability.

It is also worth emphasizing that this thesis does not focus entirely on one specific and niche field of research. It rather adopts a multidisciplinary approach and aims at setting the ground for interdisciplinarity in studying these topics. At this stage, it is worth providing clarity on the specificities of these two main approaches that are multidisciplinarity and interdisciplinarity. Alvargonzález (2011) provided an overview of such concepts, starting by defining what is meant by the word 'discipline.' In his view, 'discipline' refers to a branch of knowledge, instruction, learning, teaching, or education. The author refers to the Latin root *discere* which means 'to learn.' In other words, a 'discipline' refers to a set of knowledge that can be both taught and learned. Choi & Pak (2006) provided an explanation for each of the terms multidisciplinarity, interdisciplinarity and even transdisciplinarity. According to these authors, as referenced by Alvargonzález (2011), the three approaches are defined exactly as follows:

First, multidisciplinarity draws on knowledge from different disciplines but stays within the boundaries of those fields. Second, interdisciplinarity analyzes, synthesizes, and harmonizes links between disciplines into a coordinated and coherent whole. Finally, transdisciplinarity integrates the natural, social and health sciences in a humanities context, and in doing so transcends each of their traditional boundaries. This multidisciplinary thesis aims at integrating different fields of research, as emphasized in Figure 3 below, with the objective of identifying links and relationships between distinct disciplines, thereby setting the groundwork for interdisciplinarity.

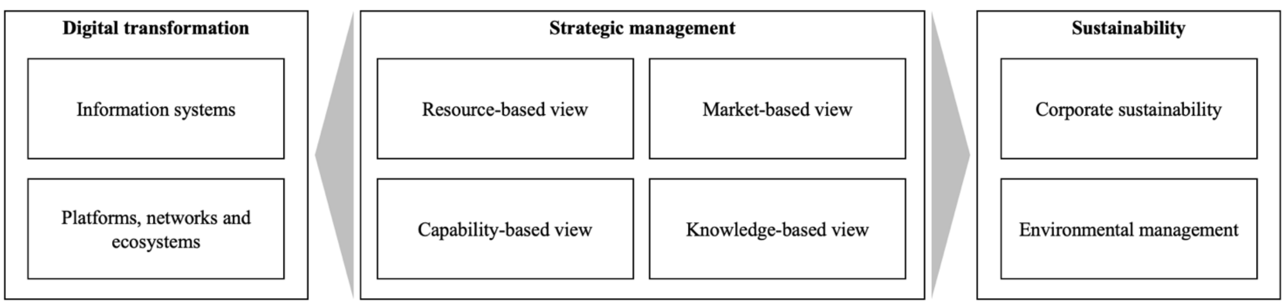


Figure 3. Literature mapping: digital transformation, strategic management and sustainability

Source: author's own development

2.1 Strategic management

The strategic management literature has long been interested in better understanding how firms gain and sustain competitive advantage (Rumelt et al., 1994). One of many different ways to summarize the building blocks of the strategic management literature is to distinguish between two early theories: the resource-based view (Barney, 1991) and the market-based view (Porter, 1979).

On the one hand, the resource-based view looks at firm-level sources of competitive advantage. According to Teece et al. (1997), this approach finds its roots in an ancient field of research which looks at corporate strengths and weaknesses. It has evolved due to evidence regarding the importance of efficiency and effectiveness, as well as the application of technological and organizational change studies to the strategy domain.

On the other hand, the market-based view is mostly based on Porter's (1979) theories related to competitive forces as well as on Shapiro's (1989) approach called the strategic conflict approach. Still according to Teece et al. (1997), the first approach related to competitive forces finds its sources in the structure-conduct-performance framework in industrial organizations' field of research (Ferguson & Ferguson, 1998). It looks at how a firm can react to competitive forces to seize a competitive advantage. The second approach, the strategic conflict approach, is focused on game theory and looks at how firms deal with competition through, for example, strategic investments, pricing, or information. Ultimately, both market-based approaches are focused on product-market positions intended to lead to competitive advantage.

The two main theories, the resource-based view and the market-based view, are complementary (Mahoney & Pandian, 1992) as firms need both to secure the right resources internally to be competitive while making strategic decisions to position themselves in regard to this competition.

Other theories have emerged over time such as the capability-based view (D. J. Teece et al., 1997) or the knowledge-based view. Both originating from the resource-based view, the dynamic capabilities are a set of capabilities necessary for wealth creation and capture in the context of rapid technological changes (D. J. Teece et al., 1997). In fast paced environments, Teece et al. (1997) suggest that wealth creation comes from these internal technological, organizational, and managerial processes that are called dynamic capabilities. The authors defined it based on

Leonard-Barton (1992) by stating that "dynamic capabilities are defined as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions."

The last theoretical domain considered, called the knowledge-based view, postulates that competitive advantage is to be found in the information captured and used by the firm. Proponents of the knowledge-based view have argued that knowledge is the most strategically significant resource for a firm (R. M. Grant, 1996) and is considered by some authors as the main determinant of competitive advantage (DeCarolis & Deeds, 1999; Winter & Szulanski, 2001).

Researchers have had different perspectives on this sub-field of research which has been used within a variety of topics (Eisenhardt & Santos, 2006), such as alliances (Mowery et al., 1996; Simonin, 1999), capabilities transfer (Szulanski, 1996; Zander & Kogut, 1995), acquisitions (Ranft & Lord, 2002; Zollo & Singh, 2004) and product development (Hansen, 1999; Hargadon & Sutton, 1997).

These different perspectives consider the knowledge-based view either as a new field within the strategy research or as an extension of the resource-based view that includes intangible assets and knowledge-based resources (Eisenhardt & Santos, 2006). Other researchers see it as an extension to organizational learning and organization theory (Kogut & Zander, 1996). Still based on Eisenhardt & Santos (2006), researchers like Spender (1996) considered knowledge as ongoing social construction and not as a resource.

In the current context, characterized by the availability of a large amount of data and potentially information and knowledge, I presented it as a distinct field within the strategic management discipline for visibility purpose. However, these debates highlight the difficulty of confining it to a specific discipline, as they highlight its many relationships with various fields of research.

Finally, two points are worth noting regarding the strategic management field of research. First, I consider both firm-level (e.g. size, managerial practices, technological change, etc.) and external market-based (e.g. industry, region, etc.) determinants of strategic advantage. This thesis will therefore build upon different theories and frameworks from the strategic management fields of research presented above. Every chapter that follows includes a literature review section that will explain in further detail the specific theory considered. The overall contributions of this thesis touch upon the different theories highlighted above and will be detailed in the third and final part of this thesis.

The second point that is worth emphasizing is that, even though it is based on the personal opinions of specific authors, this thesis embraces the vision of Drnevich et al. (2020). Concerned about the fact that (1) the strategic management has been only focused on efficient and effective management practices, that (2) researchers are not incentivized to produce impactful research that serve collective welfare, and that (3) there is a theory-practice gap between strategic management studies and executives and policymakers, the authors suggest a problem-based research that is focused on the logic of discovery of real-world phenomena.

Concretely, this thesis will tackle two real-world challenges organizations face today: digital transformation and sustainability. In the current context of rapid technological changes and reputational risks resulting from public awareness of environmental and social issues, firms are required to reinvent themselves. There is therefore an urgent need to improve our understanding on how, in terms of technologies and managerial practices, such organizations can operate.

The following sub-sections provide an introduction on the specific fields of digital transformation and sustainability and summarize the current knowledge at the intersection between both topics.

2.2 Digital transformation

Digital transformation is the first of two real-world challenges investigated in this thesis. The development of digital technologies and its various impacts, particularly on the economy, have been largely documented for decades now (e.g. Jorgenson, 2001). Back in 1998, member countries of the OECD agreed on the following definition of the Information and Communication Technologies (ICT) sector[1]: "the ICT Sector is a combination of manufacturing and services industries that capture, transmit and display data and information electronically." At this stage, it is also worth emphasizing that *technology* is broadly defined as "a tool, method, or design that help humans solve problems and achieve goals" (Alexander & Yacoumis, 2018). This thesis considers ICTs as technologies that are used to store, process and transfer information in a digital form, treating this information as a series of 1 or 0 to solve problems and achieve goals. ICTs and digital technologies are often used as interchangeable terms in the literature. Nevertheless, this

[1] https://www.oecd-ilibrary.org/docserver/factbook-2013-64-en.pdf?expires=1702559681&id=id&accname=guest&checksum=5FE8D2DD264EF5CB4528C41CFB0BDB89

thesis will favor the terminology *digital technologies* for coherence purposes, with the core area of interest being digital transformation. However, whenever citing specific papers using the *ICT* terminology, it will stick to the terminology used by the authors of these papers.

Next to definitions, scholars have also looked for ways to classify such technologies, using mostly two overlapping approaches. The first approach consists of classifying digital technologies based on their application or functional scope, while the second approach focuses on the technology itself. Regarding the first approach, Sebastian et al. (2017) referred to the SMACIT acronym, classifying digital technologies into five categories that are social, mobile, analytics, cloud and Internet of Things technologies. Still regarding the first approach, Ross et al. (2016) have developed a classification that is based on the functional scope of digital technologies, identifying five other categories that are virtualization, automation, sensing, processing and networking technologies. Regarding the technology-based approach, the OECD proposed in 2017 a new classification that is based on the international patent classification (IPC), which emerged in 2003 (Inaba & Squicciarini, 2017). The technology areas are presented in Table 1 below:

Table 1. Classification of digital technologies based on the International Patent Classification (IPC) (Inaba & Squicciarini, 2017)

Technology area	**What it enables**	**Products concerned**
High speed network	High speed communication through networks. Enhances communication ability.	Digital transmission, network (protocols, architecture, etc.), telephone communication, broadcasting, and transmission, reception, channels (see e.g. Haykin, 2001; ATIS, 2001). Wireless network technologies are not included.

Mobile communication	Wireless communication by portable devices.	Cellular systems, wireless Local Area Networks (LAN) and Personal Area Networks (PAN). (see e.g. Stüber, 2011).
Security	Security in information processing and communication.	Secret-coding, authentication, and electronic payment (see e.g. ATIS, 2001)
Sensor and device network	Communication among sensors and devices.	'Ubiquitous Sensor Networks,' i.e. networks of intelligent sensors (see e.g. ITU, 2008).
High speed computing	High speed data processing. Enhances data processing ability of computers.	Computer architecture, composition of hardware (arithmetic, logic, control, input/output, and storage units), computer programs, and operating systems (see e.g. Hennessy at al., 2012; ATIS, 2001).
Large-capacity and high-speed storage	Storage of large-capacity data and high-speed storage.	Various storage device-related technologies (e.g. semiconductor memory, magnetic storage, optical storage, etc.); network (e.g. network attached storage, NAS; storage area network, SAN); and file systems (see e.g. ATIS, 2001)
Large-capacity information analysis	Dealing with large amounts of data for analysis.	Database and numerical analysis, computational science, and computer aided engineering (see Date, 2005; Teorey at al., 2011; Strang, 2007)
Cognition and meaning understanding	High-level concept understanding.	Cognitive computing (see Wang at al., 2010).
Human-interface	Operability by human beings.	Human-interface technologies (see e.g. Raskin, 2000)

Imaging and sound technology	Processing and transmission of images and sound data.	Video equipment, television, image processing, acoustic equipment, and audio signal processing-related technologies (see e.g. Rosenfeld at al., 2014; Bovik, 2010; Spanias at al., 2006; ATIS, 2001).
Information communication device	Electronic components (both active and passive devices) realizing function of information processing or communication.	Electronic circuits, communication cables, semiconductor lasers, etc. (see e.g. ATIS, 2001).
Electronic measurement	Electronic measurement technologies utilizing information processing and communication.	Radio navigation, radio direction-finding, etc. (see e.g. Klaassen, 1996).
Others	Residual category. ICT related technologies not belonging to any of above categories.	Data input and output, hybrid computer, etc. (see e.g. ATIS, 2001)

A key drawback of the pure application-based classification is that one technology can serve multiple applications. That is the main reason why this thesis conceptually prefers the technology-based approach to investigate sustainable application domains of such technologies. With that in mind, this thesis will be particularly interested by digital technologies such as digital platforms, artificial intelligence, Internet of Things, and cloud computing. These specific technologies will be defined throughout the thesis in the dedicated chapters.

Different terms have been coined to refer to the profusion of digital technologies throughout the economy and society, such as digitization, digitalization or digital transformation. Guandalini, (2022) indicates that the literature uses digitization, digitalization, or digital transformation as interchangeable terms. However, even though these three terms are all linked with the use of digital technologies, Gong & Ribiere (2021) argue that these should be kept distinct conceptually.

Concretely, Gong & Ribiere (2021) review precise definitions of the three concepts. First, they state that digitization refers to "taking analog information and encoding it into zeroes and ones so that computers can store, process and transmit such information" (Bloomberg, 2008). Aligned with this definition, Legner et al. (2017) defined it as "the technical process of converting analog signals into a digital form."

Second, digitalization is defined as "the pace of change in a society driven by digital technological development, involving multiple technologies at different stages of maturity that will converge and create new technologies" (McAfee, 2009) and "a sociotechnical process of applying digitizing techniques to broader social and institutional contexts that render digital technologies infrastructural" (Tilson et al., 2010).

Gong & Ribiere (2021) finally performed a thorough review of digital transformation definitions and proposed a unified definition stated as follows:

Digital transformation is "a fundamental change process enabled by digital technologies that aims to bring radical improvement and innovation to an entity [e.g., an organization, a business network, an industry, or society] to create value for its stakeholders by strategically leveraging its key resources and capabilities."

The questions raised in this thesis relate specifically to the concept of digital transformation, as the goal is to understand organizational design, managerial practices and related changes associated with the adoption and use of digital technologies.

Verhoef et al. (2021) offered a review of the literature related to digital transformation specifically, stating that it has been isolated in specific business disciplines. Among the disciplines of interest for this thesis, they state that the strategic management literature for example has focused on conceptualization, operationalization, and renewal of business models (Foss & Saebi, 2018; Osterwalder & Pigneur, 2010), while information systems research has focused on technical developments that concern the adoption and use of digital technologies and resulting business value (Nambisan et al., 2017).

Furthermore, Verhoef et al. (2021) emphasize the fact that digital transformation involves multiple disciplines related to organizations, strategies, marketing or supply chains, and that there is a need for interdisciplinary research that would try to make connections between these different themes and disciplines. Moreover, they state that digital transformation is particularly relevant for incumbent firms, which will be the focus of this thesis as it is indeed interesting to investigate the changes and adaptations needed given the legacy of such organizations. They emphasize how digital technologies impact organizational structure, which will be tackled in Chapter 3 of this thesis too, suggesting that firms need to allow for experimentation and testing in separate business units, adopt agile organizational forms, and invest in digital functional areas on top of the IT department. Finally, in line with Gong & Ribiere (2021), the authors consider digitization, digitalization and digital transformation defined above as three different concepts that they see as phases. They consider (1) digitization as the simple fact of converting analog information into digital information, (2) digitalization being the application of digital technologies to improve processes and (3) digital transformation a company-wide change that may lead to the development of new business models and logic to create and capture value.

It is also worth highlighting that the extensive literature on digital technologies has long been focused on assessing the macroeconomic impact of these technologies on our economies, particularly on productivity growth. Economists like Paul Krugman noted that productivity is crucial in the long term as it determine our living standards and the wealth of nations. However, in 1987, Robert Solow stated that "the computer age is everywhere except for the productivity statistics."

As noted by Brynjolfsson & Hitt (1998), productivity is in fact hard to measure. Output, being defined as "the value created for consumers," is less straight-forward for today's information firms than for industrial ones, as it includes criteria such as product quality, customization, convenience, and many other intangibles. The same observation holds at the input side. Inputs include various indicators extending beyond labor hours such as capital equipment, materials, worker training and education and, according to Brynjolfsson & Hitt (1998), organizational capital such as supplier relationships and investments in business processes.

Next to the difficulty of relying on precise measures at the input and output side, the difficulty to assess the impacts of specific technologies might also be related to the nature of these technologies.

Researchers have indeed classified frontier technologies, such as artificial intelligence, as General-Purpose Technologies (GPT) (Cockburn et al., 2018).

According to the definition from Bresnahan & Trajtenberg (1995), GPTs are technologies that evolve and improve rapidly, have a wide range of applications, and can lead to complementary innovations. The impact of specific GPTs on economic indicators like productivity might be hard to capture due to the fact that GPTs require organizational adaptations, process innovation and complementary assets (T. Bresnahan et al., 1996). This implies that economic effects of such technologies may take time to unfold and greatly vary across firms, sectors or countries (T. Bresnahan et al., 2002). In this context, researchers have started studying the impacts of the adoption of such technologies beyond productivity indicators (Furman & Seamans, 2019), an emerging trend I aim to contribute to.

Finally, researchers such as Griliches emphasized in 1960 the importance of understanding micro-level determinants of technology diffusion and application to better understand how digital technologies influence economic indicators (Griliches, 1960). To do so, studies have looked at the adoption of such technologies under the lens of complementarities.

According to Brynjolfsson & Milgrom (2012), complementarity assessment is relevant for organizational analysis as it enables the identification of patterns in the adoption of tools or practices, their fit with business strategies and the reasons why this adoption and combination of practices differ from one organization to another. According to the same authors, complementarities can be assessed in two ways.

In one respect, the correlation test, which assesses relationships between pairs of practices, is particularly relevant when managers are aware of the complementarities and adopt sets of practices based on these known complementarities (Aral et al., 2012).

However, the performance test (N. Melville et al., 2004), which compares the results of organizations that have a certain set of practices in place with organizations that do not, appears to be more relevant when practices are randomly determined. In practice, both methods are valid. As an example, Aral et al. (2012) used both techniques to investigate three-way complementarities between three Human Resources (HR) practices and technologies being the adoption of Performance Pay, HR Analytics and Information Technology.

Based on these two methods, it appears as an evidence that the feasibility of complementarities assessment relies on two aspects. First, sufficient data on the adoption of practices or sets of practices must be available to run both correlation and performance tests. Second, the performance test is feasible if there is enough time between the adoption of practices and the analyses. Indeed, as stated above, the performance effects of the adoption of some practices or technologies, in particular GPTs, may take time to unfold and might therefore not be visible in the data.

Recently, papers such as McElheran et al. (2022), which served as inspiration especially for Chapter 2, have therefore engaged in efforts to document patterns of adoption of advanced technologies such as artificial intelligence, laying the groundwork for formal assessments of complementarities in future research. With the objective of documenting rather than explaining, the paper highlights a set of determinants for adopting artificial intelligence and bridges the gap between technology adoption and strategic management, suggesting that business strategies may influence the adoption of specific technologies such as artificial intelligence.

Besides laying the groundwork for complementarity assessment in future research, this thesis also aims to open our perspective regarding digital transformation. While the management literature has long seen firms' performance under the lens of financial performance, there is a need to extend our attention to other indicators of firms' activities and performance and to consider a broader definition of 'wealth,' going beyond economic indicators to integrate environmental and social considerations. This specific aspect is the focus on the next subsection related to sustainability.

2.3 Sustainability

The second real-world challenge investigated in this thesis relates to sustainability. Regarding its definition, Guandalini (2022) refers to Caputo et al. (2021) to emphasize the fact that the term sustainability is difficult to define due to its multidisciplinary nature and its influence on socio-economic organizations at all levels, be it in terms of actions, decisions, and behaviors.

The concept of sustainability emerged initially in the 70s and was popularized in the early 80s (Purvis et al., 2019) at a time when awareness was raised regarding the societal and environmental impacts of the different industrial revolutions. Despite the difficulty to align on a definition for *sustainability*, there has been a common understanding of the initial concept of *sustainable development*, defined in the Brundtland report in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland et al., 1987).

As indicated by Figure 4 below, Passet (1979) suggested that behind the notion of sustainability lie in fact three interrelated pillars: the economy, the society, and the environment.

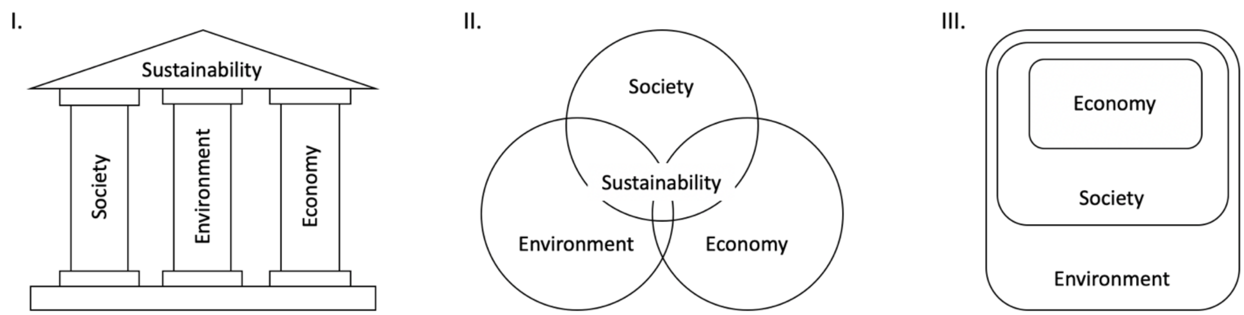


Figure 4. Three different views on sustainability: the pillar, the circle and the nested respresentations (Purvis et al., 2019)

While there is a general agreement on the fact that these three pillars are essential component of the concept of sustainability, different representations have emerged over time (Purvis et al., 2019). The literal pillar representation (see Figure 4, I.) simply highlights the fact that sustainability cannot be achieved without these three pillars together.

The circle approach (see Figure 4, II.) shows that sustainability, or sustainable practices, lies at the intersection between the three components.

Finally, the nested visualization (see Figure 4, III.) considers the three pillars as subsystems of each other. In this representation, society is part of the environment, and the economy is part of society.

Over time, different frameworks have been developed to guide society and companies towards sustainable development. The most renowned is called SDG, for Sustainable Development Goals. Next to that, and perhaps more suited to companies' context, the concepts of ESG (Environment, Social, Governance) and CSR (Corporate Social Responsibility) have also been developed. When it comes to assessing progress on such dimensions, the reality is that we have seen a profusion of environmental – or sustainability – standards, as The Economist (2020) states that more than 360 standards exist today.

Regarding research, two important streams of the literature will serve as basis for this thesis. First, the environmental management literature, which focuses on the environmental pillar as I do throughout the thesis, has been particularly interested in the study of environmental management practices (EMPs) (Montabon et al., 2007). Defined as "the techniques, policies and procedures a firm uses that are specifically aimed at monitoring and controlling the impact of its operations on the natural environment," these practices can be operational, tactical, or strategic in scope (Montabon et al., 2007).

Among the determinants of adoption of such practices, we find the regulatory environment or market pressure (Rondinelli & Vastag, 1996), as well as institutional pressures from stakeholders such as governments, regulators, customers, competitors, community, and environmental groups as well as industry associations (Delmas & Toffel, 2004).

The literature has been particularly interested in assessing the performance potential of adopting such practices. Some authors (Porter, 1991) suggest a win-win situation based on anecdotal evidence, suggesting that environmental regulation could lead to innovation that would offset the cost of compliance (Jaffe & Palmer, 1997). Other authors (Berry & Rondinelli, 1998) have focused on proactive approaches and claim a positive win-win relationship between environmental management and firms' performance through the creation of new business opportunities resulting from demand for "clean products and processes." Florida (1996), Klassen & McLaughlin (1996) or Russo & Fouts (1997) have empirically investigated the relationship between environmental management practices and financial or environmental performance, highlighting a positive relationship. Finally, Orlitzky et al. (2003) performed a meta-analysis of such studies, confirming the overall positive relationship between environmental practices and performance.

Next to environmental management in general, this thesis also relies on the literature related to environmental innovation more specifically, also known as eco-innovation. In a nutshell, innovation has long been considered one of the most important drivers of development, growth and competitiveness (Ozusaglam, 2012). Environmental innovation is defined as a specific form of innovation aiming at minimizing or reducing the impact of products and processes on the environment (Ozusaglam, 2012).

The United Nations Conference on Trade and Development (2007) defined technological innovation as the introduction of new products, process or services in the market. However, as indicated by many authors (e.g. Ozusaglam, 2012), this definition is too restrictive if we consider innovation studies as an interdisciplinary field. The so-called "OSLO Manual" published by the OECD and Eurostat define innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practice" (OECD & Eurostat, 2018). Therefore, an innovation does not need to be novel to the market to be considered as such; its novelty towards the firm in question is sufficient. Fussler & James (1996) defined eco-innovations as "new products and processes which provide customer and business value, but significantly decrease environmental impacts." Later on, Kemp and Person (2007) proposed a definition that will be retained in this thesis and that is still widely used in the literature today:

"Assimilation or exploitation of a product, production process, service or management or business method that it is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives."

This definition highlights the different scopes of environmental innovations (i.e. process, product, or business method) as well as the novelty to the firm, resulting in a reduction of environmental impact. Regarding terminology, it is worth noting at this stage that, like in the case of *ICTs* and *digital technologies* emphasized earlier, the terms *environmental innovation* and *eco-innovation* are used as interchangeable terms in the literature. For coherence and harmonization purpose and to minimize the use of jargon, this thesis favors the terminology of *environmental innovation*, except when citing papers using specifically the *eco-innovation* term.

Finally, this thesis is also interested in what the literature calls *corporate sustainability*. de Oliveira et al. (2023) recently offered a literature review on this topic. They define corporate sustainability based on Steurer et al. (2005) as "the application of sustainable development at the micro-level, that is, at the corporate level, through a short-term concern related to the economic and environmental aspects and long-term regarding the social performance of the company." Looking at the barriers and conditions to the adoption of corporate sustainability that will also be developed in this thesis, the authors make the hypothesis that new technologies such as 5G and those characterizing the fourth industrial revolution (Industry 4.0 technologies) can contribute to the integration of corporate sustainability into industrial context.

The dedicated chapters in this thesis will review the areas of knowledge and theories relevant to investigate the adoption of environmental management practices and corporate sustainability and its intersection with digital transformation. Before diving into these chapters, the next sub-section proposes a summary of the limited knowledge we have to date at the intersection between digital transformation and sustainability.

2.4 Research gaps

Knowledge at the nexus between digital transformation and sustainability remains scarce. An early study published by Berkhout & Hertin (2004) proposed a general framework to assess the overall impacts of digital technologies on the environmental pillar of sustainability. This framework has been reused, re-interpreted and re-labeled many times (Hilty & Aebischer, 2015). As depicted by Figure 5 below, it distinguishes three orders of effects and considers digital technologies as being both part of the problem and the solution to frame the complex relationships between digital and environmental sustainability.

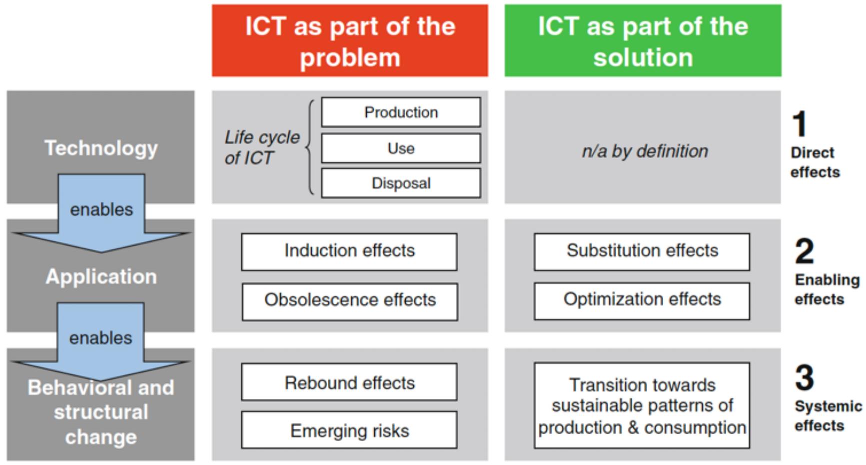


Figure 5. ICT and sustainability framework: three levels of positive and negative effects (Hilty & Aebischer, 2015)

First-order effects

First-order effects are defined by Berkhout & Hertin (2004) as negative environmental impacts resulting from the production, use and disposal of digital technologies. In other words, these relate to the lifecycle of digital products and relate to the technology itself. These effects can be assessed with a Life-Cycle Assessment (LCA) approach (Baumann & Tillman, 2004).

Even though the estimates vary from one study to another, these direct impacts are the ones with the least uncertainty, compared with the enabling and systemic effects that I will define in the following subsections. Freitag et al. (2021) offered a review of the current estimates of the total environmental impact of the ICT sector in terms of carbon emissions. The ICT industry itself is estimated to be responsible for 2.1 to 3.9% of global greenhouse gas (GHG) emissions, a share similar to the one of the aviation sector. Yet, this impact is expected to increase drastically in the coming years.

According to Freitag et al. (2021), three factors can be responsible for this increase in the direct impacts of digital. First, the efficiency improvements brought by digital technologies can lead to rebound effects, also refered to as the Jevons Paradox (Alcott, 2005). A. Greening et al. (2000) identified three sources of rebound effects and define them as follows. First, improved efficiency in the consumption of energy or other resources tend to decrease the price of that particular resource. This situation may then lead to an increase in the consumption of that resource, thereby offsetting the reduction in energy or other resource consumption enabled by the improved efficiency. This particular situation is called direct rebound effect. Second, the price decrease raised in the first point may also lead to changes in the consumption of other goods or services. In other words, the efficiency gains may simply be shifted from one resource to another. This second situation is called indirect rebound effects. Finally, the price fall of energy or other resources may lead to a price decrease further in the value chain and throughout the economy, thereby fueling consumption increase. This third and last case is called economy wide rebound effects. To sum up, potential efficiency improvements brought by the application and use of digital technologies could therefore be insufficient in the presence of such rebound effects.

Second, still according to Freitag et al. (2021), current studies of ICT's footprint make important omissions regarding expected growth trends in ICT. The authors argue that emerging technologies such as blockchain or Internet of Things are sometimes omitted from these estimates because they are not considered as ICT, thereby providing a partial picture of ICT's full impact and future trend.

Finally, the authors also argue that significant investments are being made in the uptake of blockchain, Internet of Things and artificial intelligence even though we have little evidence to date that indicates that it will save more carbon emissions than it will introduce. More recently, advances in artificial intelligence have proven to be extremely impactful for the environment. For example, training Large Language Models (LLMs) such as GPT-3 (ChatGPT) required 700,000 liters of water (Li et al., 2023) and emitted more than 500 tons of CO_2e in the atmosphere (Patterson et al., 2021).

Second-order effects

Second-order effects relate to the use of digital technologies or, in other words, to their applications.

On the negative side, digital technologies could add up to other products, thereby adding environmental pressures (F. Berkhout & Hertin, 2004). On the negative side, Hilty & Aebischer (2015) distinguish induction from obsolescence effects. Induction effects relate to an induced consumption of another resource due to the use of digital technologies. A typical example would be that a printer induces the consumption of paper and that this consumption could be higher with computers than with typewriter. The other negative second-order effect relates to obsolescence, meaning that the use of digital technologies could shorten the life of other resources due to incompatibility. Again, a typical example would be Apple iPhones limited capacity to support software updates.

On the positive side, digital technologies can bring efficiency gains in production processes as well as dematerialization of products and services (noting that the terms dematerialization or virtualization could be misleading, as digital technologies remain material in nature) (F. Berkhout

& Hertin, 2004). More precisely, Hilty & Aebischer (2015) refer to optimization and substitution effects from the use of digital technologies. These effects are still highly uncertain. The industry has produced promising estimates; for instance, the World Economic Forum (2022) stated that digital technologies could reduce global CO_2e emissions by up to 20%. However, these estimates remain highly hypothetical to date.

Third-order effects

Even more hypothetical are the potential third-order effects, also called systemic effects, defined by Hilty & Aebischer (2015) as "the long-term reaction of the dynamic of socio-economic system to the availability of ICT services, including behavioral change and economic structural change."

On the negative side, we find that rebound effects, as defined above, convert efficiency improvements into aggregate additional consumption of resources, such as emerging risks in the access to key resources.

On the positive side, digital is believed to enable more sustainable patterns of production and consumption. Among these patterns of production and consumption, the most notable patterns are the shift from *linear* to *circular* business models and, more generally, to the circular economy as well as the shift from ownership to access-based consumption thanks to the so-called *sharing economy*.

Research question

Nowadays, firms are challenged to leverage digital technologies for sustainability imperatives, but they also face changing consumer preferences, stakeholder demands and waves of competition on top of radical changes in the global institutional fabric (Hwang & Höllerer, 2020). In other words, firms are required to re-invent themselves to seize the potential brought by digital technologies while, at the same time, tackling sustainability issues.

In this context, there is a need to transform operations, products, business models and elements such as culture to integrate digital transformation and sustainability (Isensee et al., 2020 – focusing on SMEs). The framework proposed by Hilty & Aebischer (2015) enables a better grasp of the complex relationships that exist between digital technologies and environmental sustainability at large. However, an important question remains open to date: how does the integration between digital transformation, strategic management and sustainability translate within organizations?

Studies investigating questions at the intersection between digital transformation and environmental sustainability at the level of organizations remain scarce. While the potential of information systems for sustainability in general has been emphasized in different studies, be it in terms of sensemaking, decision making and knowledge creation (Butler, 2011) as well as in terms of automation (Dao et al., 2011) and innovation (N. P. Melville, 2010), the managerial and organizational complements to the adoption of digital technologies necessary to build sustainable value remain unclear.

Different papers, which will be developed in the dedicated sections of this thesis, have highlighted the need to integrate digital transformation and sustainability research (e.g. Feroz et al., 2021; Gomez-Trujillo & Gonzalez-Perez, 2022; Guandalini, 2022; Xia et al., 2022). Inspired by the research gaps currently emphasized in the literature, the main goal of this thesis is to provide answers to the following question:

How can incumbent organizations strategically operate a digital transformation in a context of rapid technological change, characterized by environmental sustainability imperatives ?

This umbrella question highlights the ambition to bridge the gaps between digital transformation, strategic management and sustainability research and emphasizes the central subject of this thesis: incumbent organizations. The overarching nature of this question serves as basis for more specific and concrete research questions which will be explained and tackled in the next chapters.

Looking at the relationships between these three building blocks, this thesis aims to shed light on the current adoption of specific technologies and practices, as well as improve our understanding of the combination of digital technologies with managerial, organizational, and strategic complements to create value that goes beyond financial value. By doing so, it aims to lay the groundwork for complementarities' assessment and for interdisciplinarity research between digital transformation and sustainability under the lens of management.

PART II: INVESTIGATING DIGITAL TRANSFORMATION AND ITS INTERACTIONS WITH STRATEGIC MANAGEMENT AND SUSTAINABILITY

1 Chapter 1: Navigating digital platforms beyond the make-or-join decision: the role of integrated value propositions

This chapter investigates the relationships between digital platforms and economic value creation for established firms. Based on a survey of over 1,300 organizations globally, we investigate the nexus between the make-or-join decision in digital platforms, integrated value propositions, and value creation, controlling for firm characteristics such as digital maturity and market categories. Contrary to the prevalent belief that the decision to act either as an owner or complementor on a platform alone can enhance market standing, our findings suggest that value creation is more significantly influenced by strategic shifts towards integrated value propositions. This research underscores the transition from traditional product-market strategies to those that are ecosystem-centric, shedding light on the importance of cooperation with external entities through the integration of products and services. By connecting digital platform use with ecosystem strategies, this chapter enriches the existing body of knowledge (see Figure 6 below) by providing vital strategic insights for firms looking to thrive economically in the digital landscape.

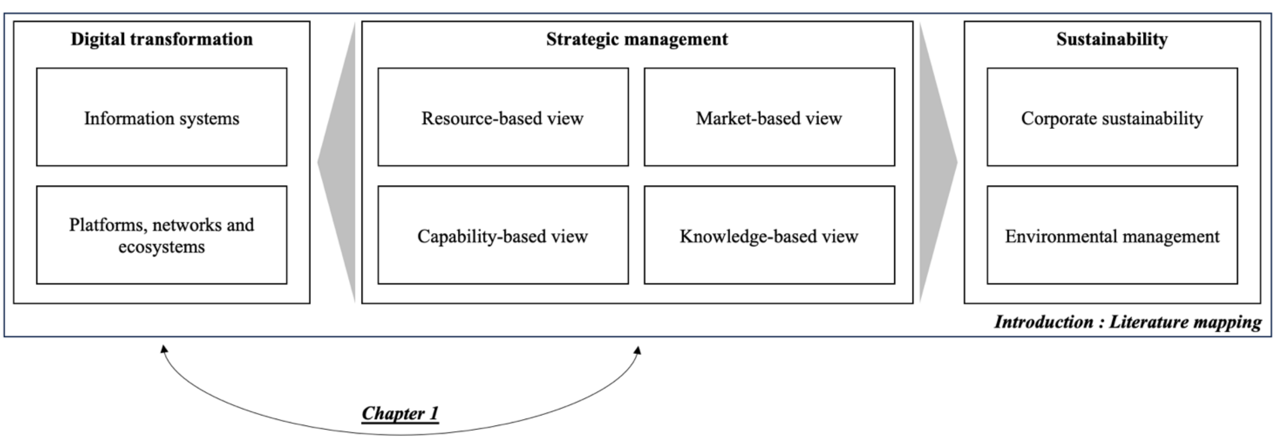


Figure 6. Literature mapping: first chapter contribution

1.1 Introduction

In the contemporary digital economy, most of the highest valued firms in terms of market capitalization are invariably platform-based (e.g. the GAFAM for Google (Alphabet), Apple, Facebook (Meta), Amazon and Microsoft). However, despite a burgeoning body of research focusing on the perspectives of platform owners (Deilen & Wiesche, 2021) and digitally native enterprises (Hermes et al., 2021), there remains a notable gap in empirical studies concerning the decision made by established firms to make or join a platform, the strategies they employ, and their contribution to value creation. This chapter aims at bridging this gap by raising two questions and underlying hypotheses. First, it aims to better understand whether the decision to make or join a platform effectively leads to higher value creation. Second, going beyond the mere make-or-join decision in digital platforms, it aims to shed light on value creation mechanisms by assessing if and how integrated value propositions influence the value creation potential of digital platforms.

The scholarly discourse around digital platforms has predominantly revolved around three analytical lenses (Hein et al., 2019): the industrial organization perspective, which probes into market dynamics (e.g. Rochet & Tirole, 2003); technology management, with an emphasis on architectural and modular design considerations (e.g. Baldwin & Woodard, 2009); and strategic management, which transitions from a market-based explanation of competitive advantage to exploring firm-specific success factors within platform contexts (e.g. Adner & Kapoor, 2010).

Concurrently, the concept of ecosystems, which surfaced approximately two decades ago, has progressively become pivotal. An ecosystem, succinctly defined, encompasses a network of interdependent firms (Jacobides et al., 2018). Iansiti & Levien (2004) elucidate that within such ecosystems, firms co-evolve their capabilities and roles, aligning with the vision and direction of one or several core companies. Core to the notion of an ecosystem is the concept of value co-creation and integrated value propositions (Autio & Thomas, n.d.; Barile et al., 2020; Quero & Ventura, 2019).

This burgeoning interest in both digital platforms and ecosystems underscores the imperative to delineate the interplay between platforms and their concomitant ecosystems. Hein et al. (2019) advocate that research on digital platform ecosystems signifies a crucial shift towards reconciling the intra-organizational technical nuances of digital platforms with the broader inter-organizational economic, business, and social dimensions of ecosystems. This paper draws inspiration from contemporary studies such as Stonig et al. (2022), which posits that value proposition integration represents a departure from traditional product-market paradigms towards an ecosystem-centric approach. Specifically, this study endeavors to bridge the theoretical divide between platforms and ecosystems through a quantitative examination of the nexus between the decision to make or join a platform, system integration strategies, and value generation.

The objectives of this chapter are twofold: firstly, to catalog the prevalence of platforms and the integration of strategic practices across diverse firm-specific and external variables; and secondly, to illuminate the interrelations between platform adoption and value creation, with a particular focus on the moderating influence of system integration strategies. Leveraging a comprehensive dataset encompassing over 1,300 firms globally across various sectors, this analysis is uniquely positioned to consider multiple dimensions, including the degree of digitalization (e.g. digitalized operations), market type (e.g. B2C vs. B2B), and the nature of firm offerings (e.g. products vs. services).

Empirical findings from our correlation analysis suggest that the simple act of adopting digital platforms does not inherently lead to value creation when accounting for external and firm-specific variables, especially those pertaining to digitalization. Nevertheless, our results highlight the critical role of strategic adaptation in platform ecosystems. Specifically, they suggest that strategic leaders should prioritize engagement with external partners and transition from a narrow product (or service)-market orientation towards a more integrated approach with these partners.

Following this introduction, the chapter will present a theoretical framework, outline the conceptual model to be employed in testing the hypothesized relationships, and describe the variables and dataset. The ensuing sections will meticulously present and discuss our findings in the context of existing theoretical frameworks before drawing conclusions.

1.2 Theoretical background

1.2.1 Digital platforms

Platforms, increasingly recognized as multi-sided markets, platform-mediated networks, or platform ecosystems, have become a pivotal element of the contemporary economy, reshaping industries and creating new paradigms for value creation and exchange (Eisenmann et al., 2011). Recent analyses underscore the profound impact of multi-sided platforms (MSP) across various sectors, highlighting their role in transforming traditional markets through digital technologies and innovative value propositions (Pousttchi & Gleiss, 2019). Today, most of the highest valued companies globally are platform-based, benefiting significantly from network effects that foster environments where winners can dominate entire markets (Cusumano et al., 2019). This phenomenon underscores the critical importance of understanding the dynamics and strategic implications of platform ecosystems in today's digital economy.

The term "platform" has been used in different overlapping research settings, resulting in various perspectives on how platforms orchestrate actors' relationships to co-create value (Lusch & Nambisan, 2015). According to Hein et al. (2019), there exist three different perspectives:

First, the economic discipline adopts a market-based or industrial organization perspective (McIntyre & Srinivasan, 2017; Parker et al., 2017), studying market power in the presence of network externalities (Rochet & Tirole, 2003) and how value on one side of the market is dependent on the number of actors on the other side (Schilling, 2002). In other words, this stream of the literature is particularly interested in network effects and the typical chicken-and-egg problem in platform settings, needing both complementors and consumers to ensure a certain value proposition (Hein et al., 2019).

Second, the technology management stream adopts a technical perspective focused on architecture and modularity (e.g. Baldwin & Woodard, 2009; Tiwana et al., 2010). It considers platforms as software-based, providing a core functionality complemented by a set of modular services through standardized interfaces, such as application programming interfaces (API). Besides the architecture and modular characteristics, researchers have also looked at the innovation potential of digital platforms and the provision of digital affordances (e.g. Nambisan et al., 2019; Tan et al., 2015), defined as “what an individual or organization with a particular purpose can do with a technology” (Majchrzak & Markus, 2012).

The third perspective is socio-technical (e.g. Constantinides et al., 2018; de Reuver et al., 2018) and is particularly interested in better understanding how platform owners integrate and govern an ecosystem of actors. This perspective encompasses strategic management studies that seek to understand sources of competitive advantage in plaform environments that, according to Adner & Kapoor (2010), depends on the capacity of firms to stimulate value co-creation with a network of complementors. This perspective moves from market explanations of competitive advantage to firm-specific factors that influence their success within platform contexts, such as timing of entry (Eisenmann et al., 2006; Schilling, 2002; Shapiro & Varian, 1999), distinction between products and/or service firms (Gawer, 2009), relationships with final customers i.e. whether business-to-consumer (B2C) and/or business-to-business (B2B) (Hein et al., 2019) or incumbency advantages like market power or firm size (Schilling, 2002; Sheremata, 2004).

Recently, Cusumano et al. (2019) have proposed a classification of platforms that distinguishes three categories: transaction platforms, innovation platforms and hybrid platforms. The latter category is called “hybrid” as it facilitates transactions while simultaneously allowing complementor innovations to be developed. Facebook is a good example of a hybrid platform. The company facilitates transactions between its users, called “friends,” while also allowing the development of third-party products such as video games.

Cusumano et al. (2019) argue that the world is increasingly moving to these kinds of platforms which operate at the ecosystem level and make a strong use of information and communication technologies. This brief review of the perspectives and considerations of platforms is particularly important for this chapter, as we investigate platforms whose main purpose is to facilitate transactions (i.e. transaction or hybrid platforms) under a socio-technical, strategic management perspective that takes both owners and complementors perspectives into account, and these two specific positions will be defined in the next subsections.

1.2.2 Ecosystems

The exploration of ecosystems in scholarly and industrial contexts has broadened our understanding of contemporary business dynamics, underpinning a shift from isolated competition to collaborative networks. An ecosystem, as conceptualized in the literature, encompasses a symbiotic arrangement among firms, each contributing to and depending on the collective success of the network (Adner, 2017). This paradigm, which mirrors biological ecosystems in its interdependencies and co-evolution, marks a significant departure from traditional competitive strategies, advocating for a more integrative and holistic approach to business strategy and analysis.

Digital ecosystems, a more specific subset within the general concept of ecosystems, underscore the transformative power of digital technology in facilitating these complex interfirm relationships. The digital ecosystem extends beyond mere technological infrastructure, embedding itself in the strategic operations and value creation processes of its constituent firms. According to Iansiti & Levien (2004), digital ecosystems thrive on the digital connections that facilitate the flow of information, resources, and value, enabling firms to co-evolve their capabilities in alignment with the overarching strategic vision of central or leading firms. The rise of platforms such as Alibaba, which explicitly references its ecosystem in its Initial Public Offering (IPO) documentation, exemplifies the critical role digital ecosystems play in contemporary business models (Jacobides et al., 2018), offering unprecedented scalability, adaptability, and opportunities for innovation.

The academic interest in ecosystems reflects this shift, with an exponential increase in ecosystem-related research, particularly in the strategy domain (Jacobides et al., 2018). This surge in scholarly attention underscores the evolving nature of business structures, from linear supply chains to intricate networks of collaboration and co-creation. Teece (2016)'s proposition that ecosystems may supplant traditional industry analyses further highlights the paradigmatic shift towards understanding business through the lens of interconnected networks rather than as isolated entities competing within rigid industry boundaries.

In conclusion, the literature on ecosystems, and digital ecosystems in particular, provides valuable insights into the evolving nature of business in the 21st century. It emphasizes the importance of collaboration, adaptability, and strategic alignment within networks of interacting firms, offering a comprehensive framework for navigating the complexities of the digital age. As businesses continue to grapple with rapid technological advancements and shifting market dynamics, the concept of ecosystems offers a robust lens through which to understand and leverage these changes for sustainable competitive advantage.

1.2.3 Digital platforms ecosystems

Research on digital platforms has highlighted the need to investigate the boundaries between platforms and ecosystems. According to Hein et al. (2019), a digital platform ecosystem comprises a platform owner that implements governance mechanisms to facilitate value-creating mechanisms on a digital platform between its owner and an ecosystem of autonomous complementors and consumers. In this context, there is a need to coordinate an ecosystem of actors while being exposed to interdependencies. Still according to Hein et al. (2019), studies on digital platform ecosystems represent a paradigm shift that integrates intra-organization technical perspectives on digital platforms and the inter-organizational economic, business and social perspectives on ecosystems. Figure 7 below depicts the different building blocks of digital platform ecosystem.

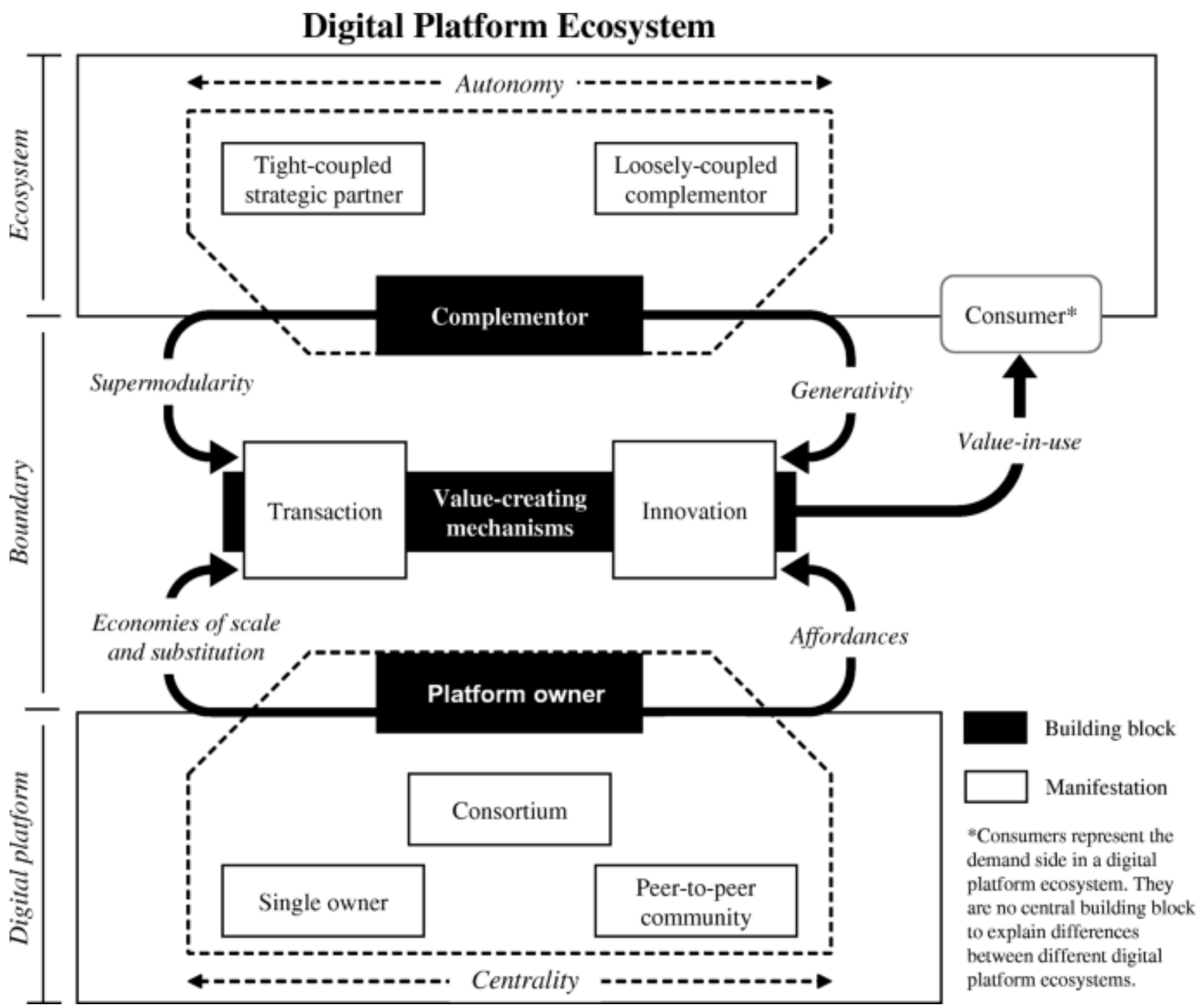


Figure 7. Building blocks of digital platforms' ecosystems (Hein et al., 2019)

Digital platforms are characterized by three types of actors: owner, complementors and consumers. As stated in their definition, the platform owner implements governance mechanisms to facilitate value creation on a digital platform. Complementors then provide complementary products or services that contribute to the platform's value proposition. Finally, consumers are the actors that benefit from these products or services and contribute to the platform by providing contents or insights on their consumption (Lusch & Nambisan, 2015).

In terms of value creation, the strategic management literature distinguishes between different meta-organizational forms (Stonig et al., 2022) that can focus on product-market, system integration and ecosystem orchestration (Jacobides et al., 2018). The product-market firm provides a product that has specific functions to consumers (Henderson & Clark, 1990), who can then combine different products.

A system integration strategy (e.g. Brusoni et al., 2001; Hannah & Eisenhardt, 2018) refers to the provision of an integrated value proposition based on multiple products.

Finally, the ecosystem-based strategy (Adner, 2017; Jacobides et al., 2018; Kapoor, 2018) focuses on the owner's or orchestrator's role and aims to align complementary products by coordinating actors through standards or platforms. As suggested by Stonig et al. (2022), integrated value proposition is the cornerstone of ecosystems' strategies, whether as complementor conducting system-based integration with external partners, or as owner orchestrating and facilitating the development of such integrated value propositions.

Although the bulk of the literature on digital platform ecosystems and value creation have focused on platform owners, several works have specifically investigated how complementors create and capture value in such settings. For instance, Ceccagnoli et al., (2012) examined how participation in an ecosystem partnership enhances the business performance of small independent software vendors (ISVs). Their study finds that joining a major platform owner's ecosystem leads to increased sales and a greater likelihood of issuing an initial public offering (IPO) for ISVs. Additionally, it demonstrates that the benefits of such partnerships are amplified when ISVs possess strong intellectual property rights or downstream capabilities, highlighting the significance of interoperability between software products and the coexistence of value cocreation and appropriation strategies in interfirm collaboration.

Research on platform ecosystems from the perspective of complementors reveals a multifaceted landscape where strategic decisions significantly impact market performance and ecosystem dynamics. Tavalaei & Cennamo (2020) explore the specialization patterns of complementors within and across ecosystems, suggesting that such strategic choices come with complex trade-offs. Inoue (2019) examines the competitive and cooperative actions of complementors in the video game industry, indicating a preference for promoting symbiotic over winner-takes-all situations. Cenamor (2021) delves into the competitive advantages that complementors can build in rapidly changing markets, highlighting the importance of strategic decisions in gaining an edge. Hurni et al. (2022) address the power dynamics between platform owners and complementors, uncovering a reciprocal process that influences ecosystem success. Marheine et al. (2021) investigate the motivational factors driving firms to become complementors in Industrial Internet of Things (IIoT) ecosystems, revealing financial, technology, and knowledge gains as key drivers. Angeren et al. (2013) focus on the Google Apps ecosystem, analyzing complementor embeddedness and its effect on innovation and ecosystem structure.

Together, these studies underscore the critical role of complementors in shaping platform ecosystems through their strategic choices, interactions with platform owners, and contributions to co-innovation and competition dynamics.

Finally, it is worth noting that Hannah & Eisenhardt (2018) proposed that firms in ecosystems balance cooperation to create value and competition to capture value. They refer to the example of Apple, suggesting that Universal Music and Apple cooperated at one point to increase revenue, while they competed to split revenue and related profit. In this paper, our focus is particularly on the aspect of cooperation through integrated value propositions, and how it contributes to value creation for firms, especially in the context of adopting digital platforms.

1.2.4 Contribution

Up until now, the study of platform ecosystems has predominantly concentrated on the viewpoint of platform owners (Deilen & Wiesche, 2021) and complementors separately, often neglecting the transition of incumbent firms toward these new models. Despite extensive evidence indicating that platforms benefit businesses, there remains a gap in research regarding how established firms, especially large incumbents, deal with digital platforms and the impact of their decision to make or join a platform on their value creation. This paper sets out to address this gap by adopting a socio-technical and strategic management lens, drawing on research from Hein et al. (2019) and (Stonig et al.(2022), to explore platform owners or complementors positions, but from the vantage point of large incumbent firms.

Our objective is to delve into the mechanisms of value creation, examining the correlation between digital platforms and firm performance. Initially, we will investigate the differences in value creation outcomes between owners and complementors of platforms. In other words, our first hypothesis aims to test the difference between the decision to make or join a digital platform for established firms. Furthermore, by synthesizing insights from studies on inter-organizational relationships and platform ecosystems (e.g. Shipilov & Gawer, 2020), we aim to scrutinize the role of integration activities undertaken by these firms. Specifically, following the insights from Stonig et al. (2022), we seek to evaluate the value creation impact of integrated value propositions with an ecosystem of partners. Unlike traditional firms that generate value within their own or their supply chain's confines, as described by Hein et al. (2019) and referred to as a pipeline business model (Van Alstyne et al., 2016), our study aims to quantitatively test a second hypothesis claiming a positive relationship between integrated value propositions and value creation. This includes examining how such integration strategies may influence the relationship between digital platforms and value creation.

1.3 Research design

1.3.1 Conceptual framework

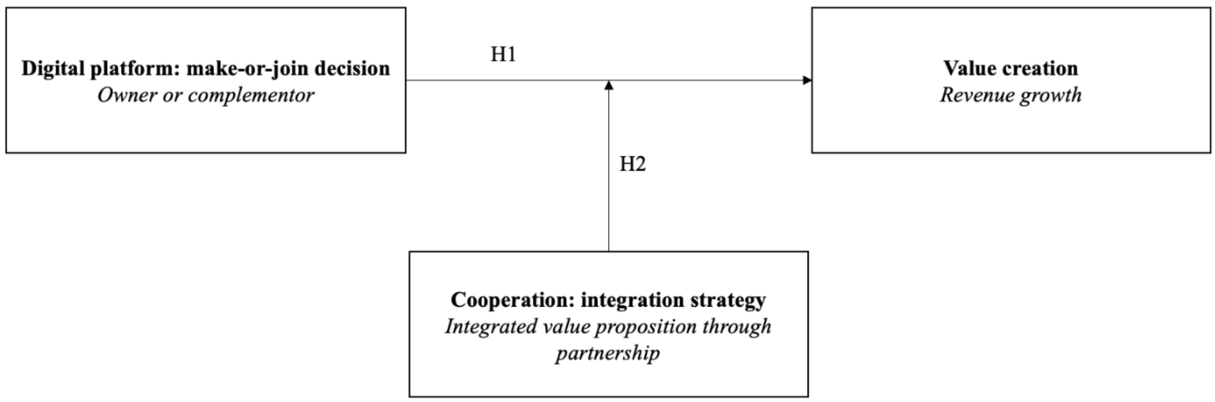


Figure 8. Chapter 1 : conceptual framework and hypotheses

Source: author's own development

Our correlation study is structured around the conceptual model depicted in Figure 8 above; grounded in the literature presented above. As explained, most studies have focused on platform firms (e.g. Van Alstyne et al., 2016). However, few studies have been able to document the adoption of platforms, whether as owner or complementor, by large incumbent firms and test the theoretical assumption which suggests that the decision to make or join a platform leads to higher value creation for them as well. Our first hypothesis is therefore stated as follows:

Hypothesis 1: The decision to make or join a digital platform is associated with higher value creation for incumbent firms.

In testing hypothesis 1, we are particularly interested in the potential heterogeneity between platform owners (i.e. make decision) and complementors (i.e. join decision). The sub-hypothesis underlying this interest is that owning a platform is associated with superior value creation.

Then, our objective is to bridge the gap between digital platforms and the underlying ecosystem (e.g. Hein et al., 2019) by looking at inter-organizational cooperation (e.g. Shipilov & Gawer, 2020). More concretely, we are interested in the potential role played by cooperation around integrated value propositions (e.g. Brusoni & Prencipe, 2001; Hannah & Eisenhardt, 2018; Stonig et al., 2022) in digital platform ecosystems and the relationship with value creation. Indeed, as indicated by Stonig et al. (2022), the source of competitive advantage has been shifting from offering standalone products and service to integrating value proposition with an ecosystem of independent firms (Adner, 2017; Hannah & Eisenhardt, 2018; Kapoor, 2018). Relying on a survey question that asks to what extent respondents partner up with external companies to offer integrated value propositions, we aim to test a second hypothesis, stated as follows:

Hypothesis 2: Cooperation around integrated value propositions plays an enhancing moderating role in the digital platform – value creation relationship.

The conceptual model presented above depicts the variables of interest only. However, the regression model used to explore the correlation between platform adoption, integration strategy and value creation takes a series of controls into account. Indeed, we complement our regression model with external (i.e. geography and industry) and firm-specific characteristics (i.e. size, digital maturity and digital incumbency) that are expected to play a role on firms' performance. Before diving into the statistical description of our variables of interest, the next section describes in greater detail the sample used as well as variables included in our analyses.

1.3.2 Data collection

The data used in this chapter comes from a survey conducted online by the McKinsey Global Institute between May 15 and May 25, 2018. It was based on a closed sample of more than 15,000 companies with a skew towards large companies. In total, our sample includes 1,303 responses from executives from all over the world and across a vast array of industries (the typical response rate was 8-12% in the country-industry pairs). The composition of the sample in each region was conceived to match the economic representation of each industry. However, it is worth noting that, while this survey offers unique data across various firms' size, industries and regions, it has been conducted by a firm having a certain relationship with the respondents (i.e. their clients), which may bring some biases.

The answers were provided by officers in charge of at least a business unit in the company and was incentivized by the access to the aggregated results of the survey. Additional quality checks, such as questions randomization, were performed. This dataset is similar in its conception to the one used in Bloom et al. (2015). While other papers such as Bughin & Van Zeebroeck (2017) have used previous versions of the survey, it is the first time this version of the survey is used in the academic literature.

1.3.3 Sample

A full description of our sample is provided in Appendix A. It shows that the data on which our analysis is based is well-varied in terms of industry, geography and type of business. As for any survey data, there are biases, but the econometric treatment given in the next sections makes sure those are accounted for when relevant. Moreover, the large cross-sectional nature of the data allows for statistically robust comparisons between different types of actors that will lend credit to the generality of the results presented here. As such, the present article contributes to the literature by generalizing local or industry-specific findings and bringing scale to the discovery in the field of digital platforms, integration strategy and value creation. The following paragraphs aim to describe the different variables used throughout the analyses to come.

1.3.4 Core variables

First of all, the *Digital platform* variable has been derived from a multiple-choice question asking: "Which of the following statements best describe your organization's use of digital platforms? (Select all that apply.)" Next to the "Other" and "Don't know" options that were left out of our analyses, five main options were proposed:

1. We own at least one platform that is used by others.
2. We use a platform to gain access to customers/partners we otherwise would not reach.
3. We use a platform to improve (or maintain) access to our current customers/partners.
4. We use a platform to monetize our data.
5. Not applicable; we do not own or use any platforms.

The definition of platforms provided in the survey is the following: “An online gateway where customers access data-enabled offerings, which are often from different sectors.”

First, a firm may own its platform and therefore act as an orchestrator. This case is composed by respondents having answered either the first option alone, or a combination of the first option and one or several of the following, excluding the fifth option (“not applicable”). Second, a firm may only use an existing platform owned by another entity, and therefore act as a pure complementor. We are confident in defining these “users” as complementors because our question specifically mention that they act as supplier on the platform, not as consumer. This treatment is aligned with the framework proposed by Hein et al. (2019) and presented in the literature section. The complementor category is composed of respondents who chose one or several options among the second, third and fourth ones. They are therefore providers of complementary products or services either to gain access to customers or partnerships that they would not reach otherwise, to improve access to current customers or partners, or to monetize data. Used as a dummy variable, the alternative option that will be left out of the regressions to come is composed by respondents having chosen the fifth option: “Not applicable; we do not own or use any platforms.”

Second, Stonig et al. (2022) recently suggested that ecosystem strategy is characterized by a shift from products to system-level collaboration around integrated value propositions. In this chapter, we are interested in assessing the potential moderating effect of integrated value proposition over the relationship between digital platforms and value creation. This measure is based on a survey question asking the extent to which the companies’ respondents agree with the following statement: “We partner up with other organizations to propose more integrated offerings.” Next to the “Don’t know” option, respondents were proposed the option to “Strongly disagree,” “Disagree,” “Neutral,” “Agree” or “Strongly agree.” Based on this question, we derive a measure of the level to which firms integrate their offerings with external partners, which we associate to the system integration strategy of firms. The variable based on the levels will be used in the descriptive part of the chapter, while for the regression analysis we rely on a dummy variable that takes the value 1 if the firm strongly agreed or agreed to the question, and 0 if they answered one of the three other options (strongly disagree, disagree or neutral).

Finally, in line with Hannah & Eisenhardt (2018) considering value creation as revenue increase, the Value creation variable is proxied by firms’ past revenue growth compared with the median of the industry they operate in. This variable is based on a survey question asking respondents their revenue growth over the past 3 years. To answer this question, respondents had to select one category of past revenue growth.[2] The “Value creation” variable is then computed by subtracting the industry’s median category from the category of each firm. The result is a three-level variable that distinguishes under-performers whose past performance has been below the industry median from median-performer and over-performer whose past performance has been respectively equal to or above the industry median.

1.3.5 Control variables

In addition to these core variables, we will include five addition control variables to account for external as well as firm-specific potential drivers of performance.

[2] The proposed buckets were the following: [–50 % or less], [–25 to –49 %], [–15 to –24 %], [–10 to –14 %], [–5 to –9 %], [0 to –4 %], [1 to 4 %], [5 to 9 %], [10 to 14 %], [15 to 24 %], [25 to 49 %], and [50 % or more].

First, the Geography control is based on the region in which the headquarters and, supposedly, strategic decisions are located. All regions of the world are represented: Europe, North America, Asia-Pacific, India and Developing regions including China, Latin America, North-Africa and Middle East. Taking the geographic dimension into account allows the consideration of potential macro differences in firms' profiles, strategies, and performances.

Second, as strategic decisions and resulting performance may also be influenced by unobservable factors at the industry level, we include a dummy variable, Industry, to account for these potential effects. As already explained, a wide range of industries are represented, but three industries are predominant in the sample. These three industries are composed of "Business, legal and professional services," "Financial services" and "High-tech." In order to avoid any misinterpretation coming from over-representation of some industries, and to be able to draw conclusions at the industry level, we have aggregated certain industries according to usual industries' grouping. From a total of 22 initial industries, we end up with 10 groups of industries that will be used throughout the analyses. These groups and their relative distribution are detailed in Appendix.

Third, regarding firm-specific controls, we include a variable that accounts for the Size of the company in terms of revenue. Size is based on the revenues declared by respondents. It is originally a categorical variable with 8 levels ranging from "Less than $10 Million per year" to "$30 Billion or more." We use this categorical variable as a continuous variable in the regression models.

Fourth, we control for the level of digitalization of the firms by relying on a measure of the proportion of core operations that are digitized. We call this variable Digital Maturity. This measure is based on a categorical variable composed of 7 levels, from "0%" to "more than 80%." Since the pace of digitization might differ from one industry to another, we subtract the average of the industry (excluding the focal company) from the category of the focal firm. We end up with a continuous variable reflecting the digital stage of firms, taking peers' situations into account.

Finally, to complete this measure of digital maturity, we add a second dimension that takes both the incumbency and digital status of firms into account. This extra variable is oriented towards firms' output, specifically sales. The variable used distinguishes traditional established firms from digital established firms and digital natives. Traditional incumbent firms are companies that are competing primarily in traditional ways (i.e. more than 80% of sales are not digital). Digital incumbent firms are established firms that have either entered new markets through digital moves and/or that are competing substantially in new ways through digitization (i.e., more than 20 percent of sales consists of digital offerings and/or new digital businesses). Finally, digital natives are firms that are born digital, and that mostly compete through digitization. Based on these three dummies (i.e. Digital Incumbent, Digital Native or Traditional Incumbent, considering Traditional Incumbent as the alternative dummy in the analyses), we also account for what we call Digital Incumbency of firms.

Table 2 below provides summary statistics for all variables. A correlation matrix is further provided in Table 7 in appendix.

Table 2. Chapter 1 : summary statistics

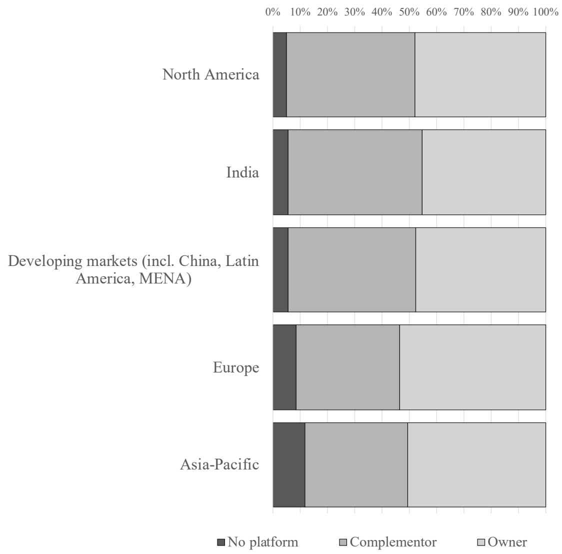
	n	mean	sd	median	min	max	range	skew	kurtosis
Platform owner	1246	0.504	0.500	1.000	0.000	1.000	1.000	-0.016	-2.001
Platform complementor	1246	0.424	0.494	0.000	0.000	1.000	1.000	0.308	-1.907
No platform	1246	0.072	0.259	0.000	0.000	1.000	1.000	3.301	8.903
System integration strategy	1246	0.590	0.492	1.000	0.000	1.000	1.000	-0.365	-1.868
Value creation	1246	2.083	0.857	2.000	1.000	3.000	2.000	-0.159	-1.622
Telecommunications industry	1246	0.072	0.259	0.000	0.000	1.000	1.000	3.301	8.903
Finance industry	1246	0.168	0.374	0.000	0.000	1.000	1.000	1.776	1.157
Public industry	1246	0.075	0.263	0.000	0.000	1.000	1.000	3.233	8.460
Manufacturing industry	1246	0.077	0.267	0.000	0.000	1.000	1.000	3.168	8.045
Transport industry	1246	0.075	0.263	0.000	0.000	1.000	1.000	3.233	8.460
Technology industry	1246	0.135	0.342	0.000	0.000	1.000	1.000	2.136	2.564
Retail industry	1246	0.100	0.301	0.000	0.000	1.000	1.000	2.658	5.067
Professional services industry	1246	0.177	0.381	0.000	0.000	1.000	1.000	1.694	0.872
Chemical industry	1246	0.064	0.245	0.000	0.000	1.000	1.000	3.552	10.622
Raw materials industry	1246	0.058	0.233	0.000	0.000	1.000	1.000	3.786	12.342
Europe	1246	0.430	0.495	0.000	0.000	1.000	1.000	0.282	-1.922
North America	1246	0.291	0.454	0.000	0.000	1.000	1.000	0.922	-1.151
Asia Pacific	1246	0.089	0.285	0.000	0.000	1.000	1.000	2.881	6.308
Developing countries	1246	0.132	0.338	0.000	0.000	1.000	1.000	2.177	2.740
India	1246	0.059	0.235	0.000	0.000	1.000	1.000	3.755	12.106
Digital maturity	1246	0.081	1.557	-0.051	-3.592	3.677	7.269	0.044	-0.618
Digital incumbent	1246	0.323	0.468	0.000	0.000	1.000	1.000	0.758	-1.427
Digital native	1246	0.111	0.314	0.000	0.000	1.000	1.000	2.478	4.142
Traditional incumbent	1246	0.567	0.496	1.000	0.000	1.000	1.000	-0.269	-1.929
Revenue	1246	3.312	2.238	2.000	1.000	8.000	7.000	0.749	-0.649
B2C	1246	0.256	0.437	0.000	0.000	1.000	1.000	1.117	-0.754
B2B	1246	0.744	0.437	1.000	0.000	1.000	1.000	-1.117	-0.754

1.4 Results

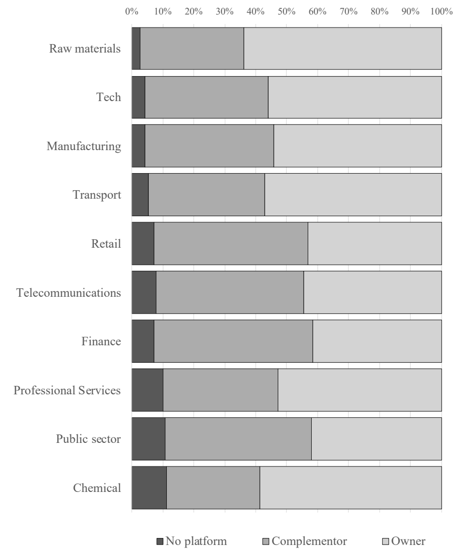
1.4.1 Descriptive analyses

1.4.1.1 Digital platform

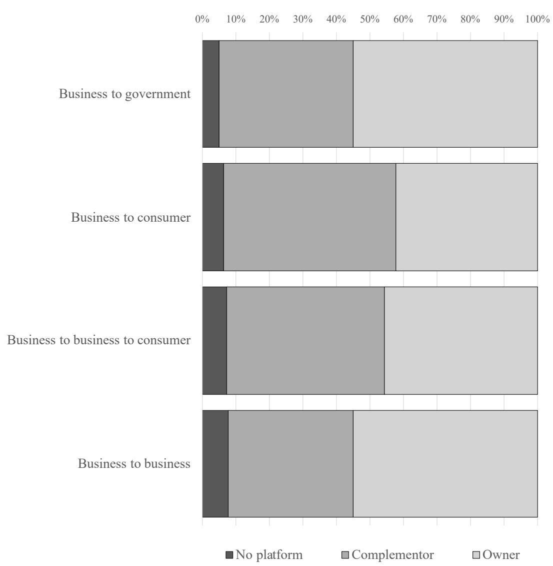
In total, 93% of companies represented in our sample have adopted a platform. If we restrict the dataset to these platform actors, we observe that 54% of platform adopters have launched their own platform (make decision) while the remaining 46% declare acting as complementor (join decision). The present section aims to document platform decisions across different characteristics, such as location or market type.



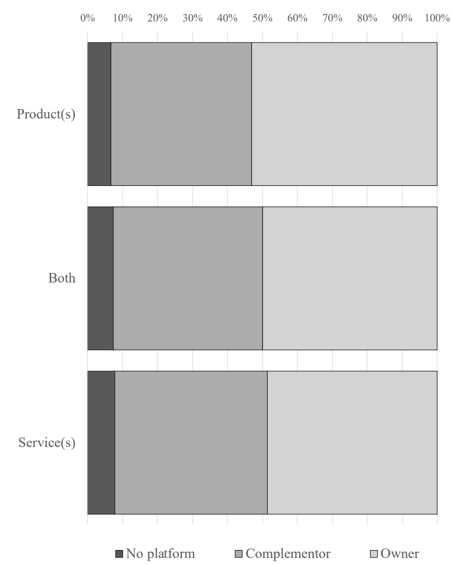
a) Digital platform position by location of headquarters



b) Digital platform position by industry



c) Digital platform position by type of market



d) Digital platform position by type of offering

Figure 9. Digital platform position by geographical origin, industry, types of market and offering

Our objective is to highlight differences in platform decisions across several dimensions[3] based on Figure 9. Regarding the proportion of firms entering or not entering the platform play, the phenomenon is relatively homogeneous across all dimensions. In other words, there are no significant differences across different locations, industries, types of markets or offerings, which leads us to the conclusion that most firms today have either made or joined platforms, regardless of the environment they evolve in.

Looking at the distinction between platform owners (make decision) and complementors (join decision), our data seem to indicate a significant difference in terms of market types. Indeed, as illustrated by Figure 9.c, our data show that there are proportionally more owners than complementors of platforms in business-to-business markets than in business-to-consumer ones. It is also worth noting that, while industries tend to show differences in the proportion of owners on Figure 9.b, differences between each pair of industries are not significant enough to draw any conclusion. Based on the data presented, we cannot confirm that, to take the two extremes on Figure 9.b, there are more platform owners in the retail industry than in the mining and raw materials industry.

The last distinction we explore is related to the digital incumbency of firms (see Figure 10 below). As a reminder, we distinguish here traditional incumbents from digital incumbents and digital natives. Our data show a significant difference between traditional and digital firms. Indeed, digital incumbents and digital natives seem more likely to make or join platforms than their traditional

[3] Please note that proportion z-tests have been performed in R to assess the significance of these differences. Heterogeneity highlighted is considered as significant if the p-value is lower that 0.05.

counterparts. If we look at the strategies in further detail, we only observe a significant difference between digital incumbent and traditional incumbents. Indeed, the proportion of platform owners is significantly higher among traditional incumbents than among digital incumbents.

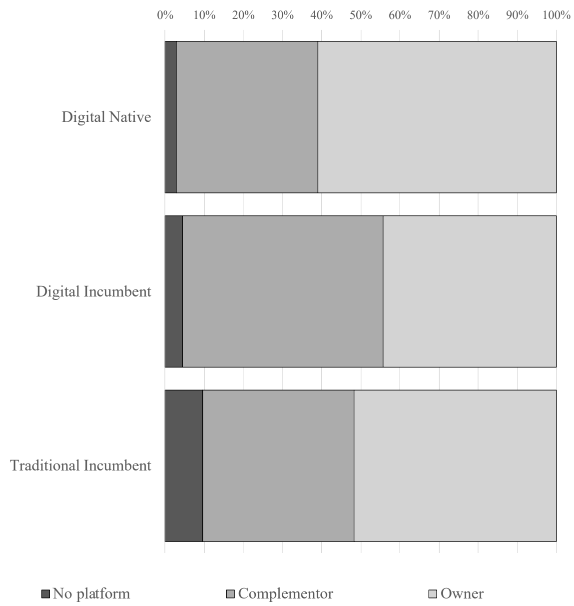
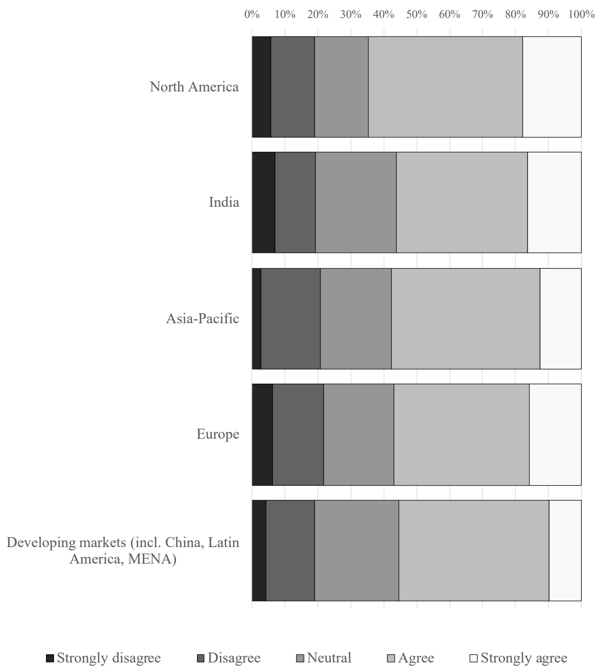


Figure 10. Digital platform position per incumbency

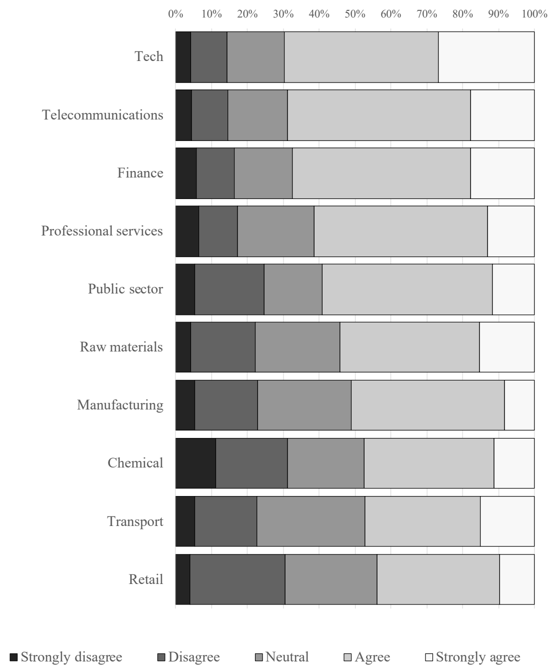
1.4.1.2 Integrated value proposition

While we have seen that a large majority of firms (93%) in our sample have already adopted a platform, we now turn our attention to their integration strategy. The first striking result we observe is that the integrative approach does not always seem to accompany the decision to make or join a platform. Indeed, only 59% of companies, either owner or complementor on a platform, declare partnering up with external organizations to offer customers more integrated offerings. Before looking closer at the intersection of digital platforms and the integration of value propositions, let us first describe this dimension across several characteristics, as we did for platforms. The following graphs are based on the complete sample data and therefore consider both platform players and non-players.

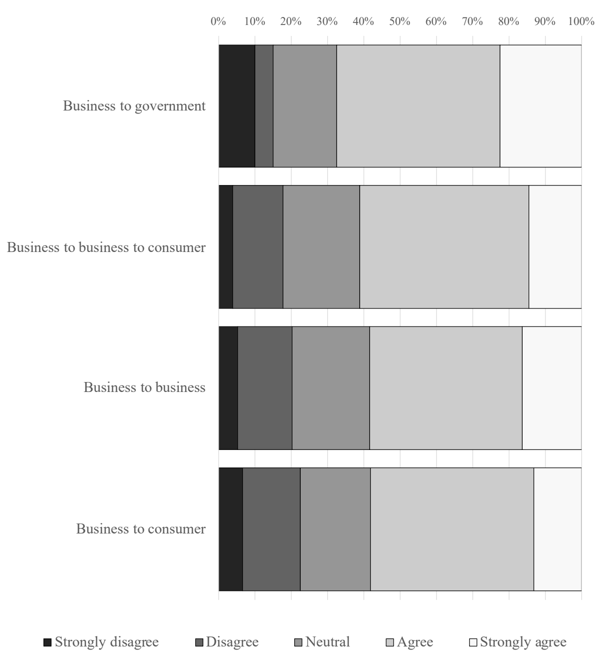
"We partner with other organizations to give customers more integrated offerings"



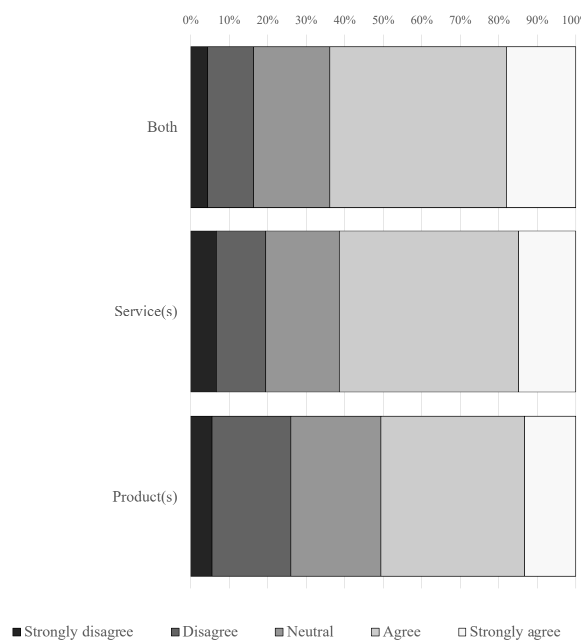
a) Integrated value proposition by location of headquarters



b) Integrated value proposition by industry



c) Integrated value proposition by type of market



d) Integrated value proposition by type of offering

Figure 11. Integrated value proposition by geographical origin, industry, types of market and offering

Looking at Figure 11.a, there is a clear difference between North America and the other regions. Indeed, it can be observed that North America has a greater proportion of companies integrating their offerings with external partners than anywhere else. This difference is statistically significant: North America's share of companies having an integration strategy is higher than in other regions. Moving on to the industries, we also observe some heterogeneity.

As depicted by Figure 11.b, there exist three groups of industries in terms of integration. First, the high tech and telecommunications industries, as well as service-oriented industries (e.g. finance, professional services), tend to have a greater share of companies that integrate their offerings than the rest. The second group is composed by the retail, chemicals and transport industries that have a lower proportion of integrating firms. Finally, the third group is composed of the remaining industries that have an approximately average share of integrating firms. While we only see a minor difference between types of markets, the types of offerings also exhibit some heterogeneity. Indeed, Figure 11.d shows that pure product firms tend to be less integrative than pure service firms or hybrid ones. These differences are statistically significant.

“We partner with other organizations to give customers more integrated offerings”

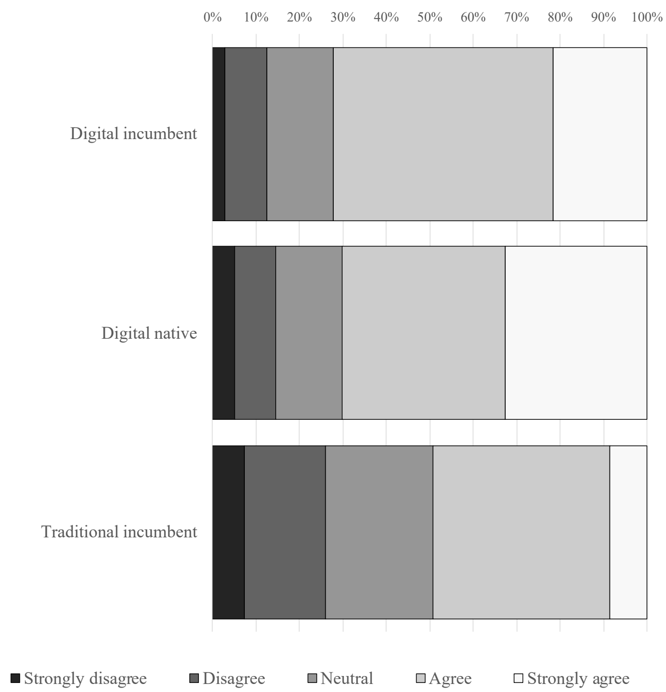


Figure 12. Integrated value proposition by digital incumbency

Figure 12 depicts the propensity to integrate offerings with external partners based on digital incumbency. While digital natives seem relatively similar to digital incumbents, they differ significantly from their traditional counterparts who have not done so. Based on this result and previous observation related to the industries, we observe that the integration strategy seems to be correlated with digitization. Digital natives or digital incumbents seem to be more likely to integrate their offerings than traditional incumbents.

To sum up, looking at the data highlights the fact that, while it appears that digital platforms are adopted by the vast majority of our sample and are equally distributed across several dimensions, the propensity to integrate offerings with external partners is less present and uniform. While interesting as a standalone factoid, it does not answer the question of whether it has an impact on value creation. Before diving into our regression analysis, let us take a look at comparative statistics between platforms and integration strategy.

1.4.1.3 Digital platform and integrated value proposition

Combining digital platform decisions and integration strategy, it can be observed in Figure 13 that there are proportionally more firms integrating their offerings with external partners among firms having entered the platform play, either as owner or as complementor, than among firms that do not own or use any platform. This observation is confirmed by statistical testing. If we look deeper at the different strategies, Figure 13 also seems to indicate that there are proportionally more integrative players among platform complementors than among platform owners. However, this difference is statistically non-significant. With these descriptive statistics in mind, we are now able to explore the relationship between platforms and performance.

“We partner with other organizations to give customers more integrated offerings”

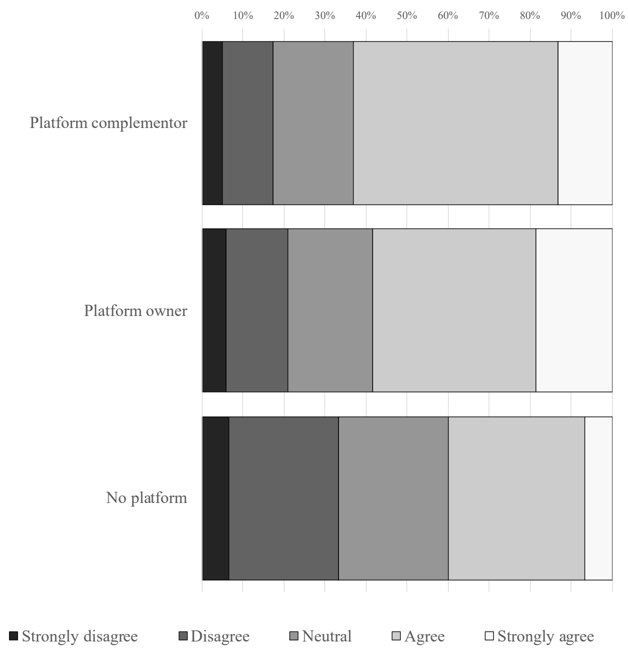


Figure 13. Integrated value proposition and digital platforms

1.4.2 Regression analyses

The objective of the present section is to further study the relationship between digital platforms, integrated value proposition and value creation. To do so, we built a multiple regression model aiming at exploring (1) the relationship between digital platform decision (i.e. make/owner or join/complementor) and value creation and (2) the moderating effect of integration strategy over the digital platform - value creation relationship.

To do so, we use a member of the generalized linear models' family: the ordered logit regression method. The model assumes proportional odds and is therefore a case of classical ordered logit application. This means that the coefficients are not directly interpretable as proportional effects. In the present econometric analysis, we are mainly concerned about the sign and significance of the coefficient: a positive coefficient indicates that the variable is positively correlated to the outcome variable while a negative coefficient indicates the opposite.

The reader interested in interpreting the magnitude of coefficients should note that data was standardized. As such, the coefficient represents the change in odds between two classes when we move a covariate by one standard deviation. This avoids oddities in the regression due to differences in scales between variables, although the data at hand is mostly on Likert scales.

1.4.2.1 Digital platforms

Authors in the field of platforms tend to indicate that entering platforms, whether as owner or complementor, correlates with higher performance (e.g. Van Alstyne et al., 2016). As it turns out, this is confirmed in our data (see Table 3, column (1)). Acting as an owner or complementor on a platform is positively correlated with value creation compared to the alternative of not adopting a platform. As already mentioned in the description of the dataset, though, most of the respondents declared to be involved at some degree with platforms. It means that the base case in such regression is relatively small.

Table 3. The relationship between platform position and value creation: ordered logit regression results

	Dependent variable:						
	Value creation						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Platform owner	0.390*	0.365*	0.431**	0.423**	0.477**	0.462**	0.388*
	(0.207)	(0.209)	(0.211)	(0.212)	(0.214)	(0.215)	(0.217)
Platform complementor	0.346*	0.290	0.375*	0.340	0.407*	0.378*	0.328
	(0.210)	(0.212)	(0.213)	(0.215)	(0.217)	(0.218)	(0.220)
Digital maturity (operations)						0.133***	0.083**
						(0.035)	(0.037)
Digital incumbent dummy							0.175
							(0.129)
Digital native dummy							1.124***
							(0.220)
Geography dummies	-	Yes	-	Yes	Yes	Yes	Yes
Industry dummies	-	-	Yes	Yes	Yes	Yes	Yes
Size (revenue)	-	-	-	-	Yes	Yes	Yes
Observations	1,246	1,246	1,246	1,246	1,246	1,246	1,246
Note:							*p<0.1; **p<0.05; ***p<0.01

When it comes to the distinction between platform owner and complementor, it is worth noting that the positive effect of owning a platform persists even with all controls included, which is not the case for complementors. However, considering the standard errors and looking more closely at the coefficients in regression (7) of Table 3, we cannot claim a significant difference in the relationship between making or joining a platform and value creation, as the magnitude of the coefficients are similar.

1.4.2.2 Integrated value proposition

As stated earlier, we assumed that an integration strategy moderates the relationship between digital platforms and value creation. The first step to assess this moderating effect is to add the corresponding variable in our model and look at any change in the digital platform coefficients. While previous results seem to confirm that companies with a platform strategy tend to create more value, these conclusions are reinforced when we control for the focal company's integration strategy.

Indeed, when we repeat the previous analysis while adding this variable to the set of factors correlating with performance (see Table 4), the relevance of adopting a platform becomes weaker in both magnitude and significance, regardless of the position adopted on the platform (i.e. owner and complementor). As one can notice, integration strategy seems to be a more important determinant of value creation in today's environments.[4]

[4] Besides the main regression, we also performed several robustness checks, both to test the influence of the choice of the dependent variable and possible endogeneity between the platform strategy and the variable of interest. The results of such checks do not alter the main conclusions presented here. They are summarized in the appendix.

Table 4. The relationship between platform position, integrated value proposition and value creation: ordered logit regression results

	Dependent variable:							
	Value creation							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Integrated value proposition	0.313***	0.299***	0.315***	0.232**	0.255**	0.290***	0.219*	0.206*
	(0.106)	(0.107)	(0.108)	(0.110)	(0.110)	(0.112)	(0.114)	(0.116)
Platform owner		0.338	0.312	0.391*	0.381*	0.431**	0.389*	0.361*
		(0.208)	(0.210)	(0.212)	(0.213)	(0.216)	(0.217)	(0.217)
Platform complementor		0.275	0.218	0.323	0.284	0.346	0.280	0.293
		(0.212)	(0.214)	(0.214)	(0.217)	(0.219)	(0.220)	(0.221)
Digital maturity (operations)							0.090**	0.078**
							(0.038)	(0.037)
Digital incumbent dummy								0.138
								(0.131)
Digital native dummy								1.095***
								(0.220)
Geography dummies	-	-	Yes	-	Yes	Yes	Yes	Yes
Industry dummies	-	-	-	Yes	Yes	Yes	Yes	Yes
Size (revenue)	-	-	-	-	-	Yes	Yes	Yes
Observations	1,246	1,246	1,246	1,246	1,246	1,246	1,246	1,246
Note:						*p<0.1; **p<0.05; ***p<0.01		

Wanting to integrate its own offer with other companies is positively correlated with revenue growth, even when accounting for whether the company has undergone this transformation or not (e.g., knowing if the webshop in the previous example somehow sells its products as complements to another company's services or products as part of a bundled offer). While this result seems to put in question part of the previous literature about the effects of adopting a platform, it is important to mention that it is not antagonistic to it; indeed, this does not dismiss the effect of platforms on revenue growth. Rather than that, it nuances it and helps highlight the mechanism through which platforms may create value: by facilitating the co-creation of value through integrating value propositions rather than by herding the consumer and decreasing search costs on both sides. Platforms are one possible way to create this joint value, but not exclusively. While it can help reaching the critical mass by bringing customers or suppliers together, more value can still come from the creation of a common proposition from different players.

1.4.2.3 Digital platforms and integrated value proposition

Having analyzed the basic model, we now turn our attention towards interactions between the digital platform and integration strategy. It is possible to use the data to query whether the willingness to integrate a company's offer with external partners, which we use as a measure of the integration strategy, has an impact on the company's platform decision impact on value creation. This is presented in Table 5, where one can see that there is a difference between platform owners and complementors that have adopted an integration strategy and the ones that have not. The base case left outside of the regressions to avoid multicollinearity is, again, the *No platform* measure. The companies in the first category tend to achieve better results in terms of revenue growth, with the magnitude and significance of the coefficients being slightly higher for owners than for complementors.

In summary, these results shed light on the importance of integrated value propositions through external partnerships, both for platform owners and complementors in today's economic environment.

Table 5. The relationship between platform position and integrated value proposition interactions and value creation: ordered logit regression results

	Dependent variable:						
	Value creation						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Platform owner w/ integrated value proposition	0.544**	0.509**	0.561**	0.547**	0.607***	0.566**	0.473**
	(0.217)	(0.219)	(0.221)	(0.223)	(0.225)	(0.226)	(0.228)
Platform owner w/o integrated value proposition	0.189	0.180	0.260	0.264	0.240	0.256	0.219
	(0.224)	(0.226)	(0.227)	(0.229)	(0.231)	(0.232)	(0.233)
Platform complementor w/ integrated value proposition	0.453**	0.419*	0.453**	0.442**	0.491**	0.445*	0.395*
	(0.219)	(0.222)	(0.222)	(0.225)	(0.227)	(0.228)	(0.231)
Platform complementor w/o integrated value proposition	0.165	0.079	0.249	0.176	0.176	0.172	0.147
	(0.235)	(0.237)	(0.238)	(0.240)	(0.241)	(0.243)	(0.244)
Digital maturity (operations)						0.127***	0.082**
						(0.035)	(0.037)
Digital incumbent dummy							0.139
							(0.130)
Digital native dummy							1.089***
							(0.219)
Geography dummies	-	Yes	-	Yes	Yes	Yes	Yes
Industry dummies	-	-	Yes	Yes	Yes	Yes	Yes
Size (revenue)	-	-	-	-	Yes	Yes	Yes
Observations	1,246	1,246	1,246	1,246	1,246	1,246	1,246
Note:							*p<0.1; **p<0.05; ***p<0.01

At this stage, it is worth noting that robustness checks have been performed and are available in the appendix. Findings remain unchanged when applying the following changes to the dependent variable: (1) using a binary dependent variable that takes the value 1 if Past Revenue Growth is higher the industry's median and 0 if equal or lower; (2) using the same binary variable based on Future Revenue Growth expectations; and (3) using Future Revenue Growth categories compared with the industry, thus categorizing performance into three levels, as used throughout this chapter. Moreover, results remain unchanged when the dataset is limited to incumbent firms by excluding the digital natives category from the sample. These robustness checks are presented in detail in the appendix.

1.5 Discussion

While this chapter does not aim to introduce a new theory, it seeks to test theoretical propositions by empirically examining digital platforms, integration strategies, and their associated value creation mechanisms. Our findings reveal heterogeneity in platform decisions across B2B and B2C sectors, as well as among different firm categories in terms of digital incumbency (i.e., digital natives, digital incumbents, and traditional incumbents).

In terms of markets, our data showed that there are proportionally more owners than complementors of platforms in B2B markets than in B2C ones. One possible explanation for this pattern could lie in the higher incidence and role of network effects in B2C than in B2B markets, due to market atomicity. Such network effects may lead to winner-takes-all outcomes, leaving little room for multiple platform owners (Katz & Shapiro, 1994). However, this hypothesis has not been empirically tested, reflecting a gap in the literature predominantly focused on B2C platforms, such as Facebook (Lee et al., 2015), Uber (Teubner & Flath, 2015), Airbnb (Zervas et al., 2017), or Apple's App Store (Eaton et al., 2015). While this chapter does not focus on the distinction between B2B and B2C markets, it is explored through the core regression model. Results are available in Table 10 in the appendix. In a nutshell, it shows that combining platforms with system integration correlates positively with value creation in both B2B and B2C markets, but the magnitude and significance of coefficients is slightly higher in B2B markets. As we have shown, these markets are characterized by a higher share of platform owners, which may influence the results. These early observations suggest platform owners need to orchestrate the ecosystem and, by definition, must integrate with external players. On the contrary, firms deciding to join an existing ecosystem may not automatically be willing to move from standalone product or service strategy to integrated value propositions and cooperation with external organizations. However, while these results provide some support that the combination of platforms and system integration is particularly important in B2B markets, more research will be needed to better grasp the potentially different value creation mechanisms between B2B and B2C environments.

Furthermore, our analysis underscores heterogeneity in platform decisions among digital firms, with digital natives being more likely to act as platform owners compared to digital incumbents. This finding enriches the literature that has largely centered on digital natives, while studies on incumbent firms adopting digital platforms remain limited, neglecting the emergence of noteworthy platforms in business-to-business environments (e.g. Sarker et al., 2012) and the potential heterogeneity between these two environments (e.g. Hein et al., 2019). Hermes et al. (2021) provide additional knowledge on this distinction between digital native and incumbent by suggesting that digital natives differ from incumbents in the sense that the latter's decision to extend beyond the make (own) or join (complement) decision to include investing in or acquiring a platform, which we do not tackle in this chapter.

Regarding integration strategies, variances based on geography, industry, and offering types are observed. North American companies, alongside those in high-tech, finance, and telecommunications sectors, are more inclined to integrate offerings with external partners. Service-oriented and hybrid firms exhibit greater integrative behaviour than pure product firms as well, likely due to the easier adaptation and combination of services with external partners' offerings compared to products.

The simple decision to enter a digital platform, whether by making it as an owner or by joining an existing one as a complementor, does not automatically enhance value creation, as evidenced by careful control for external and firm-specific factors. This aligns with the quantitative validation provided by the case study of Stonig et al. (2022), demonstrating that an integrated value proposition correlates positively with value creation, as reflected in the revenue growth of firms. Stonig et al. (2022) describe this approach as a foundational element of a comprehensive ecosystem strategy, a finding that our research supports by showing that system integration via an integrated value proposition boosts performance, as previously suggested by Lenox et al. (2007). Moreover, our findings reveal that firms generate more value by transitioning from solely enhancing their products or services to fostering positive interdependencies among products (Ganco et al., 2020) through collaboration with external partners. Thus, our analysis suggests that in the realm of digital platforms, pursuing partnerships to offer more cohesive and integrated value propositions is more beneficial than maintaining sole control over the entire offering.

1.6 Conclusion

First of all, it is worth noting that our study acknowledges three main limitations. First, while the research gathers unique strategic insights from companies' executives, the relationship that exists between the company conducting the survey and the respondent companies may include biases that are hard to identify and overcome. One bias is related to the selection of respondents and specifically to self-selection bias. While firms were equally incentivized to answer the survey by receiving the detailed results, this does not prevent a certain selection of respondents. Indeed, results may be restricted only to the firms interested in the results for certain reasons that have not been investigated. Unfortunately, the anonymity of both respondents and non-respondents has prevented us from further investigating it and therefore constitutes a key limitation to this study. Second, the company running the study may have a certain agenda driving the questions and definitions used, which may not be perfectly aligned with scientific needs and rigor in terms of theoretical conceptualization. While in our view the definition of platform provided in the survey serves as an adapted measure of transaction platforms and we expect most of the respondents to share this understanding, we cannot exclude that some of them refered to innovation platforms when answering the questions. In both cases, and as explained earlier in this chapter, our main consideration is that platforms are multi-sided environments. Knowing this, the objective has been to assess the role played by the make-or-join decision as well as the integration strategy on value creation for established firms. This research objective is applicable to both transaction and innovation platforms, as well as hybrid platforms, which represent most platforms today (Cusumano et al., 2019). The third limitation relates to the cross-section nature of the data, preventing us from making causal claims. To mitigate these concerns and enhance the reliability of our findings, we employed a dynamic cross-sectional research design that incorporates both retrospective performance metrics and future expectations, thus strengthening the validity of our conclusions. Nonetheless, further studies using longitudinal data would help uncover causal mechanisms.

This chapter critically examines the nexus between key digital platform decisions, strategic integration, and value creation within the ecosystem framework, offering a nuanced understanding of the dynamics at play in modern business environments. Through our empirical analysis, we uncover that mere decision to make or join a platform, devoid of a cohesive integration strategy, falls short of driving significant value creation. Significantly, our findings suggest a paradigm shift from traditional product or service enhancement towards collaborative efforts to forge more integrated value propositions, particularly for platform owners. This shift towards a system integration strategy may represent a transitional phase towards a broader ecosystem strategy. In doing so, our research not only provides empirical support to the theoretical discourse, as underscored by the works of Stonig et al. (2022) and Hannah & Eisenhardt (2018), but also charts a path for future inquiries into the capabilities required for successful ecosystem navigation, laying the groundwork for a deeper exploration of the balance between cooperation and competition in the digital age.

For practice, this study offers insights into the limitations of simply adopting a platform as either an owner or a complementor for achieving business success. It argues for the importance of engaging with external organizations and forming partnerships as a strategic move towards ecosystem-oriented strategies.

For research, this chapter lends quantitative support to recent literature that explores the confluence of digital platforms and ecosystems, especially the work of Stonig et al. (2022). It corroborates the view that modern firms must navigate the delicate balance between collaboration for value creation and competition for value capture, as discussed by Hannah & Eisenhardt (2018). Looking ahead, this chapter lays the groundwork for future research in one specific area. While the heterogeneity highlighted in terms of types of offerings or industries presents interesting avenues for future research, we are convinced that the mechanisms at play in B2B markets would be worth investigating. While our early results (see Table 10) already show heterogeneity supporting a greater importance of integration strategy in B2B markets than in B2C ones, it will be crucial for understanding the strategic mechanisms at play and better guide organizations to move beyond our focus of B2C platforms to include such platforms. Furthermore, future studies may also move beyond value creation to investigate value capture mechanisms, using profitability measures instead of revenue-based measures of value creation that we use in this chapter.

Finally, this research hints at the potential for studying the role of capabilities in leveraging digital platforms. Building on suggestions by Helfat & Raubitschek (2018) about the significance of integrative capabilities, future work could delve into the specific capabilities firms need to develop for successful transition from product-market strategies to ecosystem integration strategies, including capabilities related to sensing, innovation, and integration. Such inquiries would enrich our understanding of how firms can effectively navigate platform ecosystems to strike an optimal balance between cooperation and competition.

1.7 Appendix

Appendix A : Sample

The empirical distributions are shown in Figures A.1-A.4. As one can see, the focus of the survey was on professional and legal services firms as well as financial services and high-tech companies. However, there were still hundreds of respondents from other industries. At the beginning, 22 categories of industries were represented. We have aggregated some of these industries to end up with 10 groups of industries (see Table 6. A.1). The distribution of respondents by groups of industries is presented in Figure 14. A.1.

Table 6. Appendix A.1 : Grouping of industries

Group	**Industries**
1. Chemicals	Chemicals Pharmaceuticals and medical products
2. Finance	Financial services Private equity
3. Manufacturing	Automotive and assembly Aerospace and defense
4. Professional services	Business, legal, and professional services
5. Public	Public sector Social sector Healthcare systems and services
6. Raw materials	Oil and gas Paper and forest products Metals and mining Electric power and natural gas
7. Retail	Retail Consumer packaged goods
8. Tech	High-tech Advanced electronics
9. Telecom	Telecommunications Media and entertainment
10. Transport	Travel, transport, and logistics Infrastructure

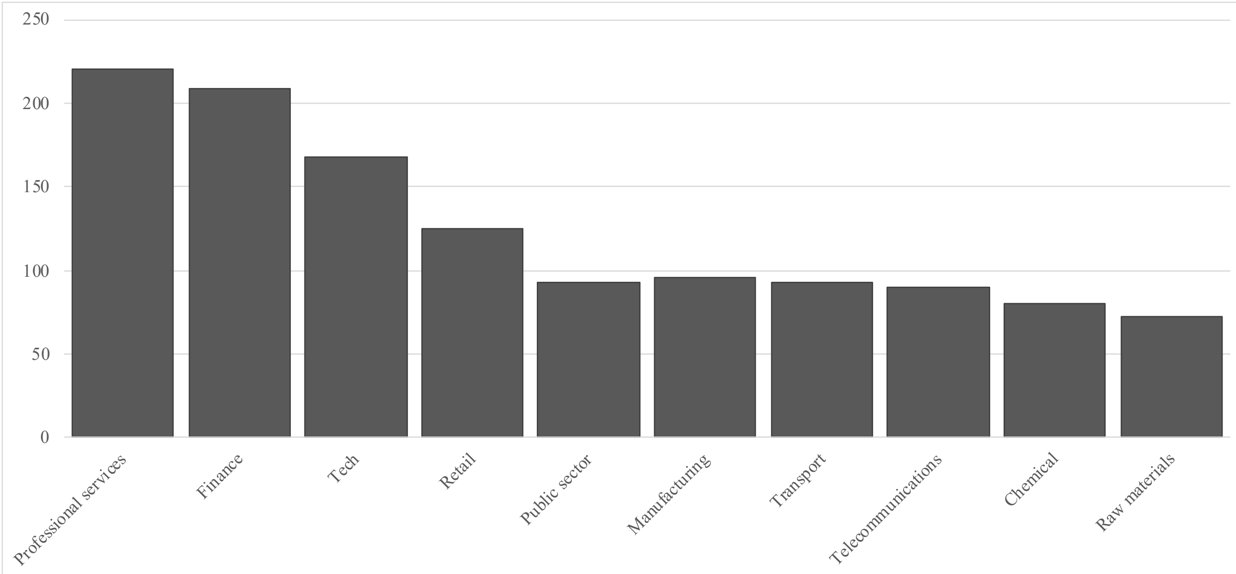
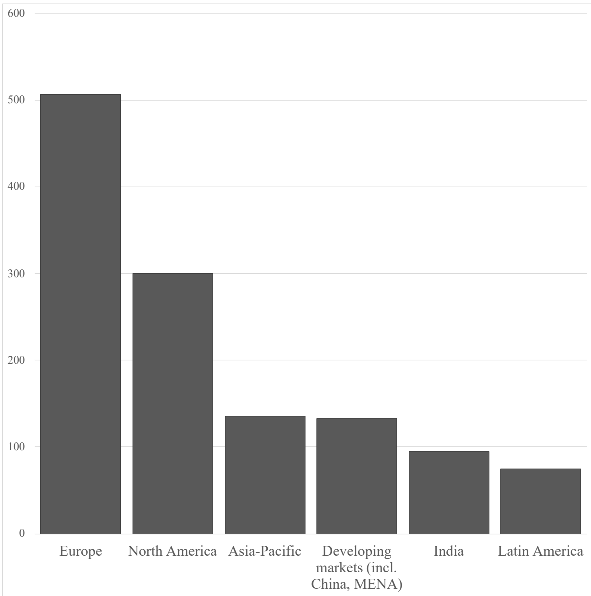
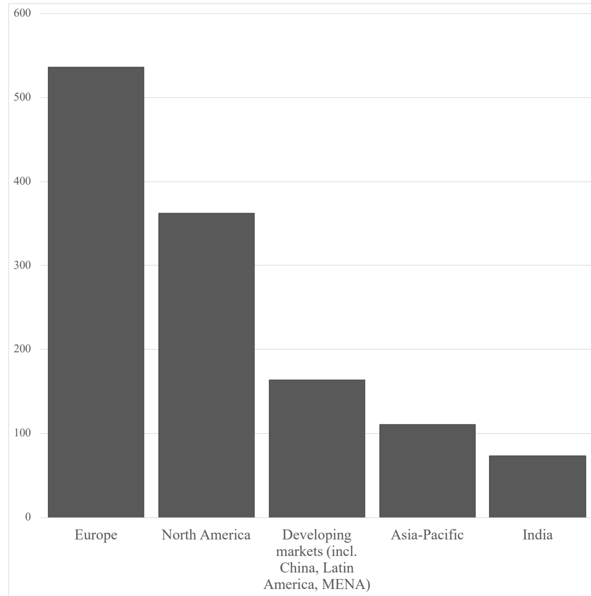


Figure 14. Appendix A.1 : Distribution of respondents by groups of industries

The geographic origin of both respondents and the headquarter of the company they work for (respectively, Figure 15. A.2.a and A.2.b) is somewhat biased towards Europe rather than North America and Asia. This might be something to account for in the analysis. However, we see that as a strength of the present study. Indeed, the academic literature tends to use data on the US or North America in general, while the European side is less prevalent. However, we control for the geographical aspect of the dataset in all our analyses.

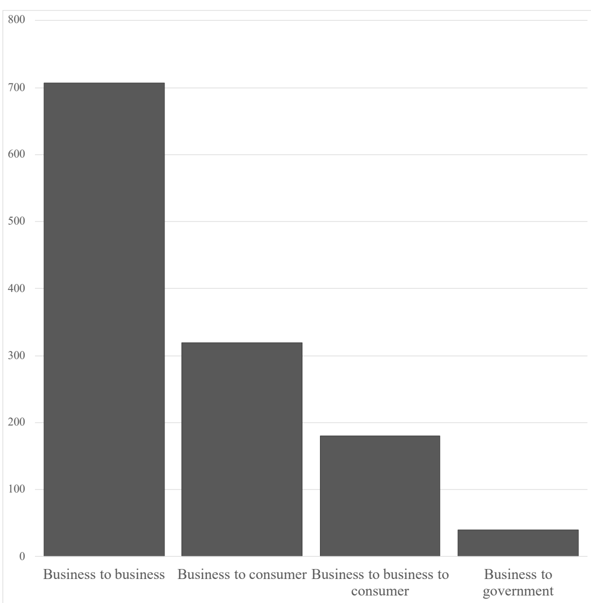


a) Distribution by geographical origin of respondents

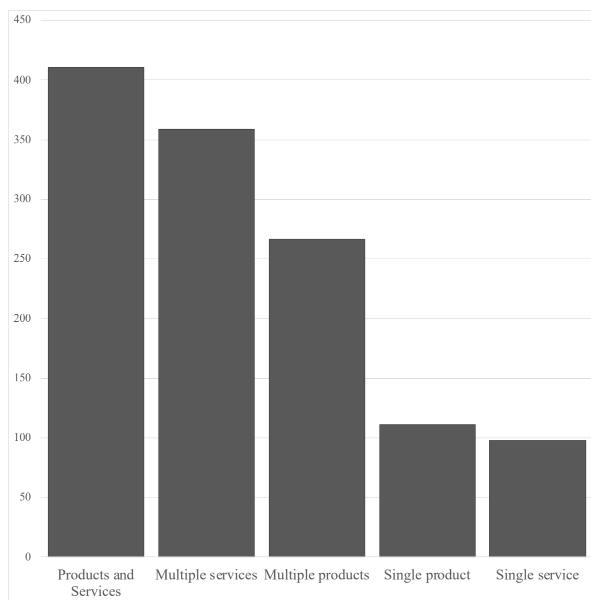


b) Distribution by geographical origin of respondents' HQ

Figure 15. Appendix A.2 : Geographical distribution of respondents



a) Distribution by type of market



b) Distribution by type of offering

Figure 16. Appendix A.3 : Distribution of respondents by type of market and offering

Finally, while there are more respondents working in business-to-business (B2B) companies than to business-to-consumers (B2C) ones (Figure 16. A.3.a), the numbers for each of the first three categories (which also include business-to-business-to-customers (B2B2C)) are all high enough to ensure a broad variety of responses. The same observation holds for what they sell. Indeed, while most of the respondents work in companies that sell more than one product or service, the spread of respondents between products, services and a combination of the two is relatively homogeneous and there remain enough observations in each of those categories to draw conclusions holding for each of them.

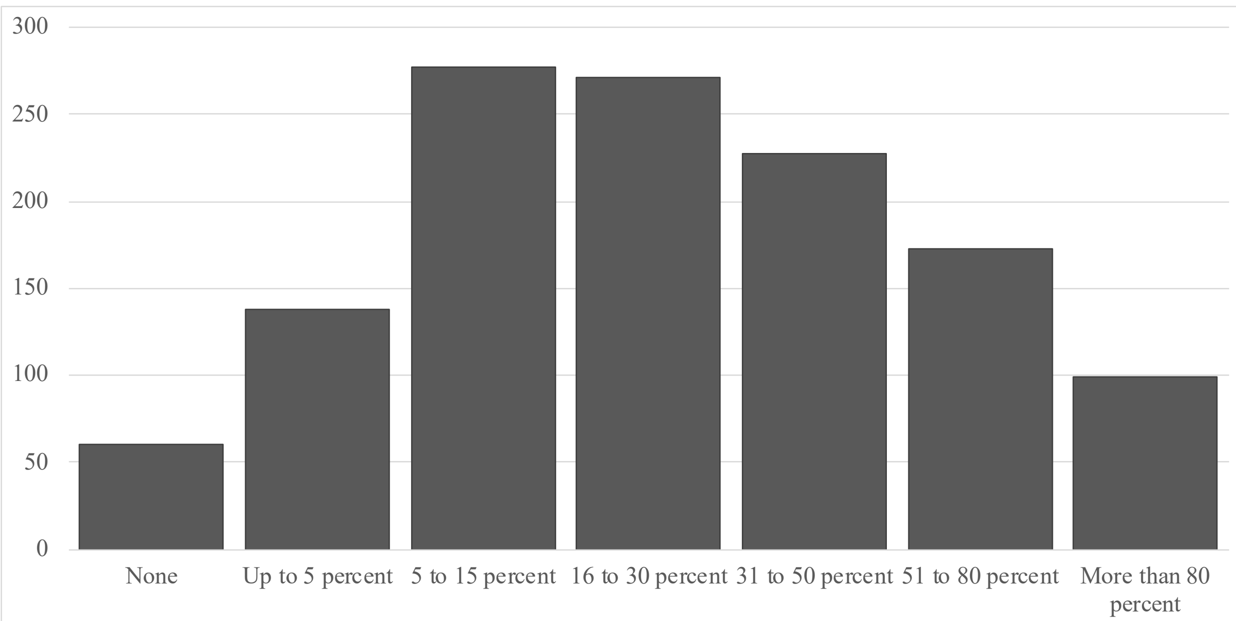


Figure 17. Appendix A.4 : Digital maturity - Percentage of core operations that are digitized

Regarding the degree to which the respondents' companies are digitized in their core processes (Figure 17. A.4), we observe what we would expect. Most of the respondents have less than 50% of their core operations that happen through digital means, while a little above a fifth of them have more than that. Finally, we have around 150 respondents who operate only through such channels. While this is certainly more than what would be observed in the economy, this is potentially due to the over-representation of high-tech and financial services in the sample rather than a systematic bias of this survey on that point in particular.

Appendix B : Correlation matrix

Table 7. Appendix B.1 : Correlation matrix of core variable and control variables

#	Variable name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	**Platform owner**	1.00																										
2	**Platform complementor**	-0.86	1.00																									
3	**No platform**	-0.28	-0.24	1.00																								
4	**Integration strategy**	-0.01	0.07	-0.11	1.00																							
5	**Value creation**	0.03	0.00	-0.05	0.08	1.00																						
6	**Telecommunications industry**	-0.03	0.03	0.01	0.06	-0.02	1.00																					
7	**Finance industry**	-0.08	0.08	0.00	0.08	0.02	-0.13	1.00																				
8	**Public industry**	-0.05	0.03	0.04	0.00	0.07	-0.08	-0.13	1.00																			
9	**Manufacturing industry**	0.02	0.00	-0.03	-0.05	0.01	-0.08	-0.13	-0.08	1.00																		
10	**Transport industry**	0.04	-0.03	-0.02	-0.07	-0.05	-0.08	-0.13	-0.08	-0.08	1.00																	
11	**Technology industry**	0.04	-0.02	-0.05	0.09	0.07	-0.11	-0.18	-0.11	-0.11	-0.11	1.00																
12	**Retail industry**	-0.05	0.05	0.00	-0.10	-0.09	-0.09	-0.15	-0.09	-0.10	-0.09	-0.13	1.00															
13	**Professional services industry**	0.02	-0.05	0.05	0.02	0.04	-0.13	-0.21	-0.13	-0.13	-0.13	-0.18	-0.15	1.00														
14	**Chemical industry**	0.04	-0.07	0.04	-0.06	-0.04	-0.07	-0.12	-0.07	-0.08	-0.07	-0.10	-0.09	-0.12	1.00													
15	**Raw materials industry**	0.07	-0.05	-0.04	-0.02	-0.04	-0.07	-0.11	-0.07	-0.07	-0.07	-0.10	-0.08	-0.11	-0.06	1.00												
16	**Europe**	0.05	-0.08	0.05	-0.04	-0.09	-0.04	0.01	-0.04	0.05	0.03	-0.06	0.02	-0.02	0.09	-0.03	1.00											
17	**North America**	-0.03	0.06	-0.06	0.07	0.00	-0.01	-0.03	0.07	-0.01	-0.09	0.10	-0.07	0.07	-0.02	-0.05	-0.56	1.00										
18	**Asia Pacific**	0.00	-0.03	0.05	-0.01	0.02	-0.01	0.01	0.03	-0.01	0.04	-0.05	-0.06	0.04	-0.04	0.04	-0.27	-0.20	1.00									
19	**Developing countries**	-0.02	0.04	-0.03	-0.03	0.05	0.08	0.05	-0.04	-0.06	0.02	-0.06	0.09	-0.06	-0.04	0.05	-0.34	-0.25	-0.12	1.00								
20	**India**	-0.03	0.04	-0.02	-0.01	0.11	0.00	-0.05	-0.04	0.02	0.03	0.08	0.03	-0.05	-0.04	0.04	-0.22	-0.16	-0.08	-0.10	1.00							
21	**Digital maturity**	-0.02	0.05	-0.05	0.13	0.11	0.01	0.00	0.00	0.00	0.02	-0.01	0.01	-0.02	-0.01	-0.01	-0.02	-0.01	0.02	0.00	0.05	1.00						
22	**Digital incumbent**	-0.08	0.12	-0.07	0.18	0.03	0.11	0.07	-0.04	-0.03	-0.03	0.02	-0.09	0.04	-0.10	0.00	-0.01	-0.01	0.01	-0.01	0.04	0.18	1.00					
23	**Digital native**	0.07	-0.04	-0.06	0.08	0.18	0.06	-0.06	-0.04	-0.07	-0.03	0.27	0.00	-0.07	-0.06	-0.03	-0.04	0.04	-0.04	-0.01	0.08	0.22	-0.24	1.00				
24	**Traditional incumbent**	0.03	-0.09	0.11	-0.23	-0.14	-0.14	-0.03	0.06	0.08	0.05	-0.20	0.08	0.01	0.13	0.02	0.03	-0.01	0.02	0.01	-0.09	-0.31	-0.79	-0.40	1.00			
25	**Revenue**	0.00	0.02	-0.03	0.04	-0.20	0.00	0.14	-0.10	0.05	0.00	-0.08	0.07	-0.24	0.14	0.10	0.06	0.05	-0.07	-0.06	-0.05	0.03	0.01	-0.12	0.06	1.00		
26	**B2C**	-0.09	0.11	-0.02	-0.01	-0.05	0.04	0.20	0.10	-0.13	0.02	-0.14	0.22	-0.18	-0.11	-0.03	-0.07	-0.05	0.05	0.13	0.00	0.02	0.01	-0.01	0.00	0.11	1.00	
27	**B2B**	0.09	-0.11	0.02	0.01	0.05	-0.04	-0.20	-0.10	0.13	-0.02	0.14	-0.22	0.18	0.11	0.03	0.07	0.05	-0.05	-0.13	0.00	-0.02	-0.01	0.01	0.00	-0.11	-1.00	1.00

Appendix C : Robustness checks

Alternative dependent variables and models

In order to assess the robustness of our results, we have built three alternative measures of value creation. The first one is still based on past revenue growth but compares two groups of companies: the first group is composed by firms that have higher revenue growth compared with the industry's median, while the second group has either median revenue growth or a revenue growth below the median. Therefore, we end-up with a binary dependent variable that takes the value 1 if the company has over-performed compared with the median, and 0 if it has not. The second and third alternative dependent variables takes Future Revenue Growth (expectations) as an indicator of value creation. It is either built as a binary variable, as we did with past revenue growth, or on the three levels of revenue growth. The results shown in Table 8. C.1 confirm our conclusions. Indeed, when taking a measure based on past revenue growth, these results also show that the value creation effect of the interaction between platform and integration strategy seem more relevant for platform owners than for platform users. We see that both the coefficients and the significance are higher in the case of platform owners than platform complementors. If we now look at columns (2) and (3) in the same table, it can be observed that the value creation effects are greater when using indicators of future revenue growth. However, this measure is based on expectations from firms' executives and may involve more biases than with the past performance measure. What is striking is that both platform owners and platform complementors with integration strategy show better expectations in terms of future results. This conclusion holds with both the probit and ordered logit models. As a reminder, the probit model distinguishes over-performers from the rest, while the ordered logit model is based on three levels of performance: under-performance, median-performance or over-performance.

Table 8. Appendix C.1 : The relationship between platform position, integrated value proposition and value creation: regressions results using alternative models and measures of value creation

	Dependent variable:		
	Value creation Past revenue growth Dummy	Value creation Future revenue growth Dummy	Value creation Future revenue growth Categories
	probit	*probit*	*ordered logistic*
	(1)	(2)	(3)
Platform owner w/ integrated value proposition	0.299*	0.390**	0.613***
	(0.160)	(0.166)	(0.235)
Platform owner w/o integrated value proposition	0.139	0.098	0.259
	(0.165)	(0.172)	(0.239)
Platform complementor w/ integrated value proposition	0.255	0.312*	0.481**
	(0.162)	(0.169)	(0.237)
Platform complementor w/o integrated value proposition	0.127	0.054	0.043
	(0.172)	(0.179)	(0.251)
Digital maturity (operations)	0.045*	0.053**	0.056
	(0.026)	(0.026)	(0.038)
Digital incumbent dummy	0.212**	0.170*	0.333**
	(0.088)	(0.091)	(0.131)
Digital native dummy	0.781***	0.783***	1.363***
	(0.138)	(0.140)	(0.221)
Geography dummies	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes
Size (revenue)	Yes	Yes	Yes
Observations	1,246	1,246	1,246
Log Likelihood	-767.608	-721.956	
Akaike Inf. Crit.	1,579.216	1,487.912	
Note:			*p<0.1; **p<0.05; ***p<0.01

Finally, we also tested some potential endogeneity issue between platform decision and integration strategy. Applying the Heckman probit method, we found essentially the same correlation as the one presented in the main article.

Sub-sample of incumbents

Secondly, we were interested in assessing whether these results were robust when limiting the sample to incumbent firms, and this is shown in Table 9. C.2. While we still control in regression (4) for the digital state of companies (in terms of output, as described in Section 5), we observe that results remain unchanged. In this case, results show that the integrative approach is crucial for both platform owners and complementors, even if the magnitude and significance of the coefficients are higher for platform owners than for complementors. In conclusion, results are robust to changes in the dependent variables and to changes in the sample studied in terms of incumbents' digital profiles.

Table 9. Appendix C.2 : The relationships between platform position, integrated value proposition and value creation: regressions results restricted to incumbents firms (i.e. excluding digital natives)

							Dependent variable:
							Value creation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Platform owner w/ integrated value proposition	0.388*	0.359	0.417*	0.407*	0.463**	0.445*	0.413*
	(0.226)	(0.227)	(0.229)	(0.232)	(0.233)	(0.234)	(0.235)
Platform owner w/o integrated value proposition	0.175	0.178	0.237	0.252	0.230	0.248	0.241
	(0.231)	(0.233)	(0.235)	(0.237)	(0.239)	(0.239)	(0.239)
Platform complementor w/ integrated value proposition	0.385*	0.348	0.398*	0.385*	0.418*	0.393*	0.352
	(0.226)	(0.229)	(0.230)	(0.233)	(0.235)	(0.235)	(0.238)
Platform complementor w/o integrated value proposition	0.104	0.022	0.194	0.125	0.132	0.134	0.117
	(0.242)	(0.244)	(0.245)	(0.248)	(0.249)	(0.250)	(0.250)
Digital maturity (operations)						0.086**	0.075*
						(0.038)	(0.039)
Digital incumbent dummy							0.147
							(0.131)
Geography dummies	-	Yes	-	Yes	Yes	Yes	Yes
Industry dummies	-	-	Yes	Yes	Yes	Yes	Yes
Size (revenue)	-	-	-	-	Yes	Yes	Yes
Observations	1,108	1,108	1,108	1,108	1,108	1,108	1,108
Note:							*p<0.1; **p<0.05; ***p<0.01

Appendix D : B2B and B2C exploration

Table 10. Appendix D.1 : The relationship between platform position, integrated value proposition, type of market (i.e. B2B/B2C) and value creation: ordered logit regressions results

	Dependent variable:						
	Value creation						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Platform w/ integrated value proposition in B2C	0.417*	0.360	0.453*	0.412*	0.497**	0.449*	0.364
	(0.240)	(0.243)	(0.245)	(0.248)	(0.250)	(0.251)	(0.254)
Platform w/o integrated value proposition in B2C	-0.069	-0.158	0.054	-0.019	0.024	0.025	-0.033
	(0.257)	(0.259)	(0.263)	(0.265)	(0.267)	(0.268)	(0.270)
Platform w/ integrated value proposition in B2B	0.528**	0.503**	0.530**	0.531**	0.573***	0.531**	0.462**
	(0.210)	(0.212)	(0.214)	(0.216)	(0.218)	(0.219)	(0.222)
Platform w/o integrated value proposition in B2B	0.266	0.241	0.327	0.317	0.282	0.292	0.268
	(0.218)	(0.220)	(0.222)	(0.223)	(0.225)	(0.226)	(0.227)
Digital maturity (operations)						0.127***	0.081**
						(0.035)	(0.037)
Digital incumbent dummy							0.141
							(0.130)
Digital native dummy							1.107***
							(0.219)
Geography dummies	-	Yes	-	Yes	Yes	Yes	Yes
Industry dummies	-	-	Yes	Yes	Yes	Yes	Yes
Size (revenue)	-	-	-	-	Yes	Yes	Yes
Observations	1,246	1,246	1,246	1,246	1,246	1,246	1,246
Note:							*p<0.1; **p<0.05; ***p<0.01

2 Chapter 2: Unveiling relationships between digital technologies and environmental innovation: the twin transition in European firms

The advent of the *twin transition* in Europe marks a concerted effort to synergize digital transformation with sustainability initiatives. This research aims to fill a gap in management literature by investigating the adoption of both digital technologies (i.e. Internet of Things, cloud computing, immersive technologies, smart robotics and artificial intelligence) and environmental innovation (i.e. process innovation, product innovation and business model innovation), thereby delineating the specific contributions of digital technologies to environmental management. Our study spans an analysis of 10,000 European firms, providing insights into the prevalence of adopting both digital technologies and sustainability innovations. In a nutshell, our results reveal heterogeneous associations between technologies and environmental innovations, suggesting a transversal role of Internet of Things and a more specific contribution of technologies like smart robotics and artificial intelligence. Given these results, this chapter not only charts an emerging research domain at the nexus of digital transformation and sustainability (Figure 18) but also opens doors for research into complementarities and performance impacts of such integrations, both financially and environmentally. By suggesting the existence of a common latent factor underlying the adoption of specific technologies and practices, it sets the stage for subsequent inquiries into the strategic and organizational implications of the *twin transition*.

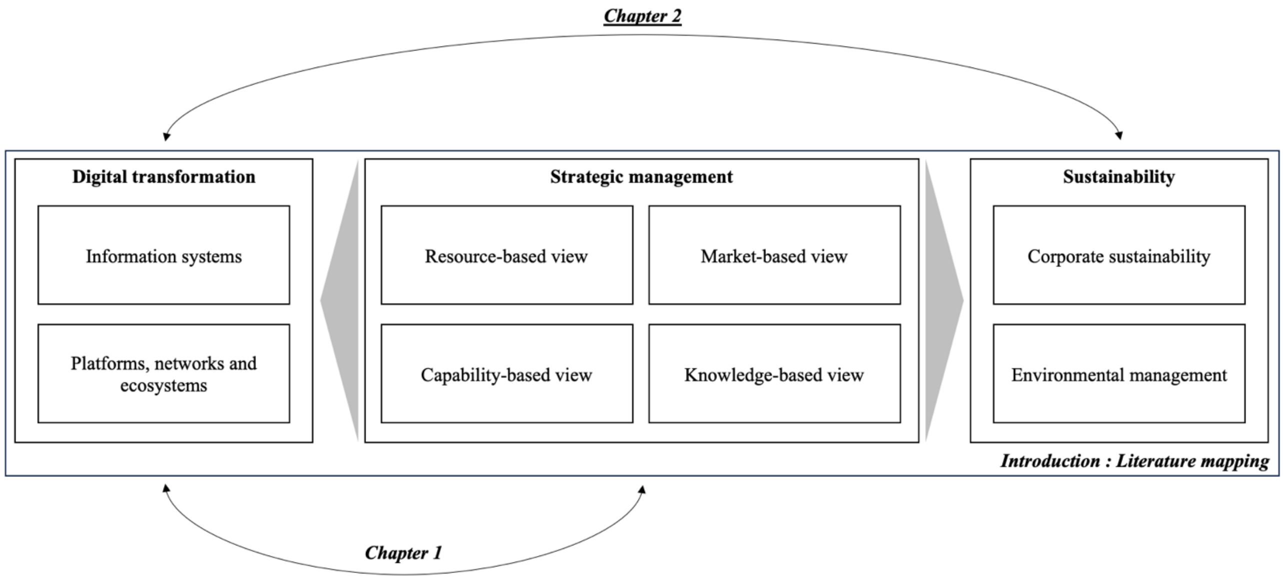


Figure 18. Literature mapping: second chapter contribution

Source: author’s own development

2.1 Introduction

As indicated in the introduction part of this thesis, today’s world is profoundly transformed by two major (r)evolutions. The first one is related to the sustainability transition, while the other relates to the digital transformation of our economies and societies. Recently, regions such as Europe have put the integration between these two transformations high on their agenda. A term was coined for it: the *twin transition* (e.g. Muench et al., 2022). In essence, the *twin transition* aims at leveraging the potential of digital technologies (e.g. Khan et al., 2023) to tackle the sustainability transition.

Recent advances in artificial intelligence, for example, and particularly its learning, are expected to lead to increased productivity and spark a revolution in business processes and models (Aghion et al., 2017; Brynjolfsson & McAfee, 2012, 2014). It is also considered an invention in the method of invention (IMI) (Griliches, 1957), meaning it could support a revolution in the way we innovate and develop new ideas, which are increasingly harder to find (Bloom et al., 2020). On top of that, other technologies such as Internet of Things and a wide range of sensors for data acquisition and analysis in manufacturing plants or onboard vehicles may also help fight energy inefficiencies. For example, UPS claims that its ORION system (On-road Integrated Optimization and Navigation) can lead to a total saving of 100 million miles and a 100,000 metric ton of CO_2 emissions.[5] Davenport (2013) considers it as the world's largest operations research project. Beyond this anecdotal evidence, knowledge regarding the adoption of both digital technologies and environmental innovation remains scarce. Montresor & Vezzani (2022) is one of the few papers that has quantitatively shown a positive relationship between specific digital technologies and environmental innovation.

Being able to look at specific technologies and types of environmental innovations, this chapter aims to refine our understanding of the relationships between both issues by highlighting the joint presence of technologies like Internet of Things, smart robotics and artificial intelligence and specific types of environmental innovation at the level of processes, products and business models. Thanks to a unique large-scale dataset representing originally 10,000 firms across all EU member states and industries, our objective is first to document the adoption digital technologies and environmental innovation.

Then, relationships between digital technologies and environmental innovation adoption are investigated. More specifically, this chapter looks at the relationships between digital technologies and environmental innovations at the level of processes, products/services or at the level of the entire business model. First, we confirm a positive association between the intensity of digital technologies' adoption and the intensity of environmental innovation (i.e. number of environmental innovation type of practice adopted). Second, we build up on Montresor & Vezzani (2022) and refine our understanding of the relationships between digital technologies and environmental adoption by assessing heterogeneity between specific technologies when it comes to their relationship with environmental innovations.

[5] https://www.forbes.com/sites/bernardmarr/2018/06/15/the-brilliant-ways-ups-uses-artificial-intelligence-machine-learning-and-big-data/, last accessed May 26, 2023.

The contribution of this chapter is to enrich theory by investigating the *twin transition* at a more granular conceptual level compared with, for example, recent work by Montresor & Vezzani, (2022). Besides academia, the objective is also to inform practitioners, such as policymakers, about the current adoption rates of digital and sustainability practices as well as about early associations between both topics, which can help better directing digital investments toward sustainability goals. At this stage, due to data limitations, this work does not aim at predicting financial or sustainability outcomes of the use of digital technologies in combination with environmental innovation. Moreover, causal interpretations are out of reach in this chapter, which aims to open doors for the formal assessment of complementarities in future research.

The chapter is organized as follows: Section 2 provides a targeted review of the knowledge on digital technologies and environmental innovation, highlighting how we are attempting to bridge the gap between these two academic fields. Section 3 describes the survey, sample, and variables we focus on as well as the conceptual framework considered. Section 4 documents in details the adoption of a wide range of digital technologies and environmental management practices and explores the relationships between both topics. Finally, Section 5 concludes our study, emphasizes the contributions of our work and opens doors for future research.

2.2 Theoretical background

2.2.1 The organizational complements of digital productivity

To better understand how digital technologies influence economic indicators and in particular productivity, researchers such as Griliches (1960) were early to emphasize the importance of understanding micro-level determinants of technology diffusion and application. Many studies after have looked at the adoption of such technologies under the lens of complementarities with managerial practices (Brynjolfsson & Hitt, 2000). According to Brynjolfsson & Milgrom (2012), complementarity assessment is relevant for organizational analysis, as it enables to identify patterns in the adoption of tools or practices, their fit with business strategies and the reasons why this adoption and combination of practices differ from one organization to another.

As explained in the introduction of this thesis, complementarities can be assessed in two ways. On one hand, through the correlation test (Aral et al., 2012), which assesses relationships between pairs of practices and is particularly relevant when managers are aware of the complementarities and adopt sets of practices based on these known complementarities. On the other hand, through the performance test (N. Melville et al., 2004), which compares the results of organizations with a certain set of practices in place against organizations that do not, and appears to be more relevant when practices are randomly determined. In practice, both methods are valid. For example, Aral et al. (2012) used both techniques to investigate three-way complementarities between three Human Resources (HR) practices and technologies being the adoption of Performance Pay, HR Analytics and Information Technology.

However, the feasibility of complementarities assessment relies on two elements. First, sufficient data on the adoption of practices or sets of practices must be available to run both correlation and performance tests. Second, the performance test is feasible if there is enough time between the adoption of practices and the analyses. Indeed, the performance effects of the adoption of some practices or technologies may take time to unfold and therefore might not be visible in the data. In this chapter, the correlation approach is favored. The main reason behind this choice lies in the fact that performance effects (be it in financial or environmental terms) may not be visible yet in the data, as firms may only be in their infancy in leveraging digital technologies for environmental sustainability.

Recently, papers such as McElheran et al. (2022) have engaged in efforts to document patterns of adoption of advanced business technologies such as artificial intelligence, laying the groundwork for formal assessments of complementarities in future research. One aspect the paper highlights is that size strongly predicts adoption of at least some advanced artificial intelligence technology, and leading sector in terms of artificial intelligence adoption rates include Manufacturing, Health Care, Information and Professional Services. Moreover, McElheran et al. (2022) consider that firm heterogeneity in artificial intelligence adoption and deployment may find its source in business-level strategies that can be distinguished by being either growth-oriented or cost-oriented (Porter, 2008). According to the authors, business strategies may influence the adoption of such technologies given the differing economics of growth-focused strategies that can come at the expense of short-term productivity versus cost-cutting applications of such technologies (Porter, 2008).

Even more recently, Agrawal et al. (2023) have looked at the importance of system-wide changes for the adoption of artificial intelligence, considered as both a constraint and an opportunity. On top of adoption determinants such as system-wide changes highlighted by Agrawal et al. (2023), early studies such as Griliches (1957) have been interested in the effects of technologies, suggesting that they could support innovation processes. In other words, such technologies are considered as "Invention in the Method of Invention" (IMI), and used as an input to innovation.

If this suggestion appears to be true, productivity might not be sufficient to assess the full potential of digital technologies like artificial intelligence, which are supposed to foster a revolution in business processes but also business models (Brynjolfsson & McAfee, 2014).

2.2.2 Environmental innovations as techno-organizational systems

Economic developments and innovations have brought benefits since the first industrial revolution, but not without causing harm. In this context, the concept of "sustainability" emerged in the late 20th century with the publication from the Club of Rome "Limits to growth" in 1972. Purvis et al. (2019) studies the evolution of the concepts related to sustainability, highlighting the importance of three pillars: the economy, the society, and the environment. Although different representations of sustainability exist, these three pillars are common to all definitions, albeit under different names (Purvis et al., 2019). This chapter focuses on the environmental pillar of sustainability. In this regard, Cainelli et al. (2012) emphasized the importance of environmental innovations to reach sustainable growth (e.g., Europe 2020 strategy, Becker et al., 2020) and competitiveness (e.g., Porter & van der Linde, 1995). Environmental innovations are defined as (OECD & Eurostat 2018):

"the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life-cycle, in a reduction of environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives."

Overall, the literature states that environmental innovations can be related to products or services, to production processes but also to management or business methods. When it comes to innovation studies, Cainelli et al. (2012) highlight the need for an environmental innovation theory that would address the effects of environmental innovations at different levels of analysis, meaning technologies, organizational processes, and societal issues (OECD, 2000). The same authors argue that environmental innovations should be considered not as standalone innovations but rather as part of systems, encapsulating regional components but also firm-level drivers such as R&D. Focusing on networking and spatial relationships (agglomeration economics) and international strategies as drivers for environmental innovation, Cainelli et al. (2012) also include other potential drivers such as the adoption of ICTs (e.g. Horbach, 2008; Mazzanti & Zoboli, 2009) to enrich their investigation. Their result suggests a strong association between the adoption of environmental innovation and ICT. Karakaya et al. (2014) explained that the Environmental Technologies Action Plan (ETAP) (Calleja & Delgado, 2007) defined eco-innovation – environmental innovation – as any innovation that benefits the environment by embracing technological innovation, process innovation and business innovation. As we are interested by the intersection between technologies and environmental innovations at different levels (i.e. processes, products/services and business models), we will retain this broad definition that reflects the techno-organizational nature of such innovations.

2.2.3 Digital technologies and environmental innovation

In a context where consumers are becoming increasingly aware of the environmental impact of products and are interested in sustainable purchasing and consumption (Robertsone & Lapiņa, 2023), firms need to limit environmental impacts. Still according to Robertsone & Lapiņa's (2023) review of the literature, digital transformation contributes to the competitive advantage of companies by enabling innovation in processes, products/services, and business models (e.g. Beier et al., 2022). According to Dalenogare et al. (2018) and Frank et al. (2019), technologies such as Internet of Things, big data, cloud computing, robotics, and artificial intelligence are the most predominant technologies of the fourth industrial revolution. These technologies offer potential in terms of flexibility (Dalenogare et al., 2018), efficiency (Jabbour et al., 2018), resource sharing (Liu & Xu, 2016) and competitiveness and growth for organizations (Stock & Seliger, 2016), due to their reliance on real-time data (e.g. Thoben et al., 2017).

Today, there is a need to better understand how digital technologies contribute not only to innovation in general, but particularly to environmental innovation. Cainelli et al. (2012) emphasized the need for further research on the relationships between digital technologies and environmental innovations specifically. However, evidence regarding the joint presence of digital technologies and environmental innovation at firms' level still remains scarce, even though there is a lot of hope in the political sphere (e.g. Muench et al., 2022) for advanced technologies like artificial intelligence and Internet of Things to solve the environmental crisis. These technologies are considered as enabling technologies that can help radically transform processes and business models, thereby reaching higher efficiency and flexibility (e.g. Holmström et al., 2016) as well as minimizing environmental impacts (e.g. Jena et al., 2020). However, most studies are based on case studies or remain theoretical in nature as confirmed by Guandalini (2022), or only look at this question at a macro level (e.g. Cainelli et al., 2012).

As explained in the introduction section of this thesis, Hilty & Aebischer (2015) proposed a framework linking digital technologies and environmental sustainability. This framework considers digital technologies (ICT) as part of both the problem and the solution. It highlights three levels of impacts: first-level direct impact (production-use-disposal effects), second-level enabling impacts (applications effects) and third-level systemic impacts (system-level effects). To date, the academic literature has been concentrated on assessing the direct impacts of digital technologies. For example, Freitag et al. (2021), described in the introduction of this thesis, provides a thorough and critical review of the estimates of the ICT sector impacts. In terms of CO_2 emissions, the authors state that ICTs' share of global Greenhouse Gas Emissions are as high as 2.1-3.9%. On the application side, which is the focus of this chapter, estimates mostly come from the industry itself (e.g. Global Enabling Sustainability Initiative (GeSi), Global System for Mobile Communications (GSMA), etc.) and suggest important abatement potential of ICT, stating that it could decrease overall CO_2 emissions by 20% (World Economic Forum, 2022).

Highly hypothetical, these estimates of positive impact of ICT might be significantly overestimated, as they are mainly based on generalizations of the best cases and neglect long-term impacts such as rebound effects (Freitag et al., 2021).

2.2.4 Motivation

There is a lack of understanding today on the actual joint presence and potential relationships of both digital technologies and environmental innovations. Antonioli et al. (2018) confirmed the positive relationship between ICT introduced to efficiently managed processes and products and the adoption of environmental innovations, particularly for more polluting firms. They also show that environmental innovation is still poorly integrated in firms' strategies. However, when it is integrated, firms try to introduce ICT as a support strategy to environmental innovations. Montresor & Vezzani (2022) is another rare study that investigates the relationship between the adoption of specific technologies and the adoption of eco-innovation based on a large sample of Italian firms. In brief, they show that (1) specifically AI and (2) bundling digital technologies are associated with a higher propensity of eco-innovation adoption at the level of production processes or models. Moreover, they also show that the adoption of technologies and eco-innovations increases with firm size.

The purpose of this chapter is to further explore how the twin transition unfolds within firms by asking the following question: How are digital technologies and environmental innovation currently adopted by firms and how do these two sets of technologies and practices relate to each other? The question is important because, in many firms, sustainability and digitalization still have separate reporting and decision lines.

To tackle this question, it is crucial to start documenting the diffusion of digital technologies and early relationships with environmental innovation practices in order to be able to formally assess, in the near future, whether complementarities materialize or not. George et al. (2021) recently emphasized the need to open the discussion on the sustainability applications of digital technology. In her review of the literature, Guandalini (2022) suggests that in this context, there is a need for joint alignment of both sustainability and digitalization streams of literature and to move beyond specific use cases and explore the phenomenon across industries and geographies. This recent study (Guandalini, 2022) calls for the development of a new stream of literature and to further align the management literature to the societal needs, including businesses, governments or international organizations. Finally, Khan et al. (2023) emphasize the significance of these topics today and the need to assess digital technologies' influence on sustainability-related innovations (e.g. Bai et al., 2020; Mubarak et al., 2021), confirming that the strength of this association is still unknown (Piccarozzi et al., 2022).

This chapter tackles the gaps identified by papers in diverse streams of the literature (e.g. Guandalini, 2022; Khan et al., 2023, Piccarozzi et al., 2022). It is deeply inspired and aligned with efforts such as McElheran et al. (2022) as well as Montresor & Vezzani (2022) to produce research with practical and societal value by sharing facts about current phenomenon and identify new avenues of research that bridge the gap between ICT adoption and environmental innovation. More concretely, the motivation for this chapter and its contribution to the literature is twofold.

First, it specifically builds upon Montresor & Vezzani (2022) and documents the adoption of both digital technologies and environmental innovation, looking at potential firms' size, industrial or regional heterogeneity.

Second, and still building upon Montresor & Vezzani (2022), it offers refined insights on the digital technologies and environmental innovation relationships by being able to assess the associations at a more granular level. We are indeed able to look at the technology level as well as investigate types of environmental innovation specific technologies may relate to. Although exploratory, the relationships investigated in the present chapter provide initial evidence regarding the joint presence of digital technologies and environmental innovation within companies. This lays the groundwork for future research, similar to Antonioli et al. (2018), that investigate the performance effects of ICT and environmental innovations adoption at the company level. In general, this chapter aims to serve as the basis for future research on complementarities between digital and sustainability issues.

2.2.5 Conceptual framework and contribution

Khan et al. (2023) have recently proposed a comprehensive summary of the literature at the intersection between digital technologies and environmental innovations. This review of the literature suggests that studies have been particularly interested by the link between digital technologies and process innovation, followed by the development of new business models and products. The red squares in the conceptual framework below (Figure 19) proposed by Khan et al. (2023) emphasize the specific technologies and environmental scopes investigated in the literature. Even though Khan et al. (2023) put the focus on the manufacturing industry by restricting concepts like Fourth Industrial Revolution or Industry 4.0 to smart manufacturing, we suggest that technologies listed under the Industry 4.0 umbrella may impact sectors well beyond the manufacturing industry. Indeed, technologies like Internet of Things, big data, robotics or artificial intelligence may impact a wide range of sectors that are worth considering when assessing the relationships of such technologies with environmental innovation. The list of technologies depicted in Figure 19 below therefore served as an inspiration for the final selection of technologies investigated in this chapter.

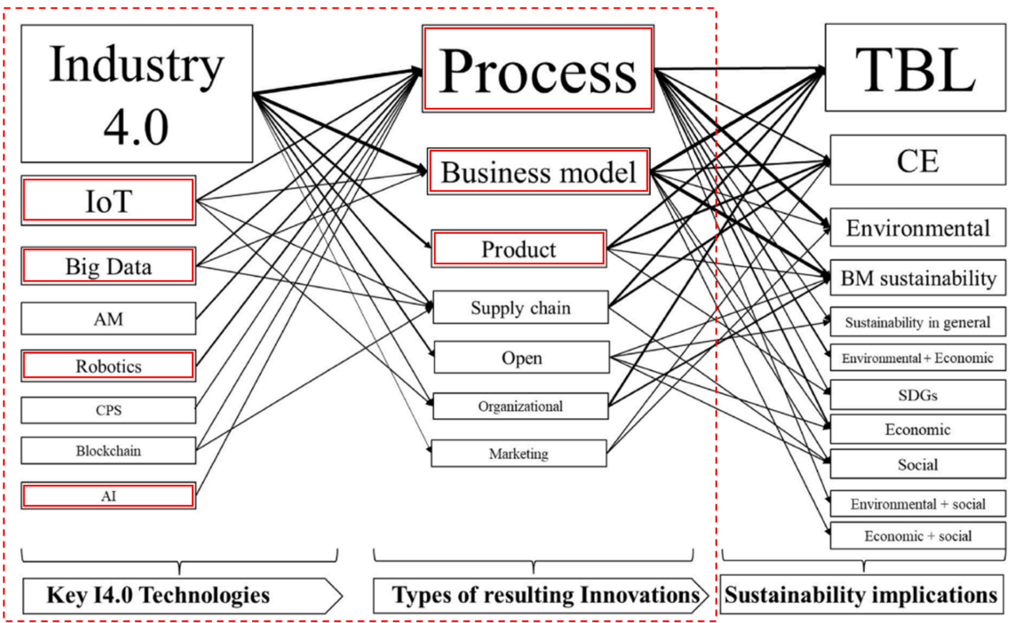


Figure 19. Chapter 2 : conceptual framework (adapted from Khan et al., 2023)

As explained, we start from the comprehensive review by Khan et al. (2023), as well as other recent work like Montresor and Venazzi (2023), with the aim of refining our understanding on the relationships between digital technologies and environmental innovations. To do so, we will look at the relationships highlighted in the succint model below (Figure 20). The objective is to look at both the relationships between digital intensity (i.e. number of technologies adopted, as explained in the previous sub-section) and environmental innovation intensity (i.e. number of environmental innovations, as explained in the previous sub-section), as well as between specific technologies and specific types of innovations that can relate to process, products or business model. As already emphasized, we are not able to draw any causal interpretation from this analysis of the joint presence of technologies and innovation practices, and performance effects of the potential complementarities between these technologies and environmental innovations are out of scope of this chapter. The core variables are described in the next section.

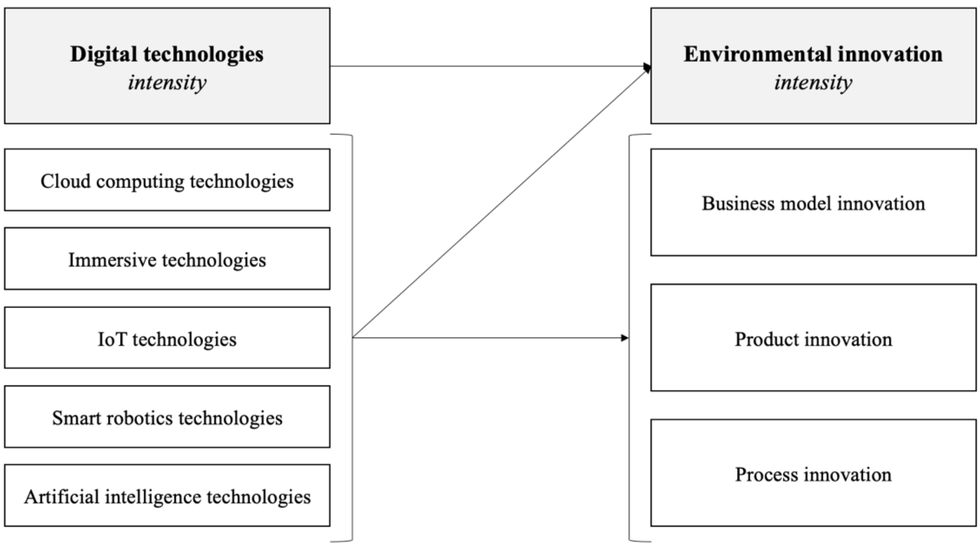


Figure 20. Chapter 2 : simplified conceptual framework

2.3 Research design

2.3.1 Data collection

This chapter is based on a survey conducted by our team at Université Libre de Bruxelles in partnership with IPSOS for The Directorate-General for Communications Networks, Content and

Technology (DG CONNECT) of the European Commission. It is the first large-scale survey across all EU member states and industries that looks at both the adoption of digital technologies and environmental management practices.

Data have been collected through computer-assisted telephone interviews performed by IPSOS. The average response rate across all countries was 6%, representing a total of 10,000 respondents across EU 27 member states, Norway and Iceland as well as across all NACE sectors. The fieldwork was conducted between 25 January 2021 and 29 March 2021. Within EU27 (excluding Norway and Iceland), 9,467 interviews were conducted. In terms of the interviewed person, the target respondent for micro and small firms was defined as an employee who knows how technology is used in the firm, while for medium and large firms, we targeted a *senior* employee who knows about how technology is used in the company in order to ensure that this senior respondent was also aware of environmental actions being taken by his/her firm.

2.3.2 Sample

Target units of analysis are enterprises with a certain degree of autonomy i.e. headquarters.

These respondents are of four different sizes in terms of employees, from micro to large enterprises:

1) micro (5-9 employees)
2) small (10-49 employees)
3) medium (50-249 employees)
4) and large (250+ employees)

It is worth emphasizing that micro-enterprises counting less than 5 employees were excluded from the sample as the content of the survey was also less relevant for these specific enterprises. These represent a large proportion of the total universe of EU enterprises and their absence in the data could therefore bias the results. Still, in terms of representativeness, it is worth emphasizing that the original sample is slightly skewed towards large firms to allow for comparisons between countries. Table 11 below depicts the number of firms represented per country and size category, as well as the proportion of each country and size categories.

Table 11. Sample description: size and country distribution

		5-9 employees	10-49 employees	50-249 employees	250 employees or more	Total
	Proportion of total sample	35.40%	35.28%	21.62%	7.70%	100%
Italy	6.87%	271	254	108	17	650
Germany	6.39%	195	177	173	59	605
France	6.35%	196	222	119	65	601
Netherlands	5.71%	150	143	139	108	541
Poland	4.79%	130	138	130	55	453
Spain	4.72%	124	144	119	60	447
Belgium	4.52%	152	144	108	24	428
Romania	4.48%	131	150	108	35	424
Denmark	4.40%	153	144	86	33	417
Bulgaria	4.38%	146	160	92	17	415
Sweden	4.37%	137	166	86	25	414
Finland	4.26%	156	177	54	16	403
Portugal	4.16%	137	138	86	33	394
Austria	3.86%	142	111	87	25	365
Czech Republic	3.65%	108	110	92	35	346
Greece	3.61%	137	138	54	13	342
Hungary	3.00%	108	88	65	22	284
Ireland	2.96%	98	94	66	22	280
Latvia	2.88%	106	88	68	11	273
Estonia	2.85%	124	121	22	3	270
Slovakia	2.76%	102	94	53	11	261
Slovenia	2.42%	108	99	17	5	229
Croatia	2.28%	82	77	38	19	216
Lithuania	2.25%	81	83	44	5	213
Luxembourg	1.27%	49	50	16	6	120
Cyprus	0.54%	19	19	12	1	51
Malta	0.26%	6	12	6	1	25
Total	100%	3351	3340	2047	729	**9467**

In terms of sectors, Table 12 shows that the top 3 industries represented in the sample are Manufacturing (19.69%), Trade and Retail (19.52%), and Construction (12.61%). At the bottom of this list, we find Water & electricity supply, Waste management and Oil and gas industries each representing around 1% of the total sample. The IT sector represents 4.84% of the sample.

Table 12. Sample description: size and industry distribution

		Between 5-9 employees	**Between 10-49 employees**	**Between 50-249 employees**	**More 250 employees**	**Total**
	Proportion of total sample	35.40%	35.28%	21.62%	7.70%	100.00%
Manufacturing	19.69%	484	663	519	199	1865
Trade, retail	19.52%	800	643	318	87	1848
Construction	12.61%	446	467	212	70	1195
Other technical and/or scientific sectors	8.08%	286	245	170	63	764
Transport	6.25%	190	207	140	55	592
ICT	4.84%	175	175	88	20	458
Human health	4.43%	129	128	91	71	419
Food	4.36%	165	128	89	30	413
Agriculture, forestry and/or fishing	3.57%	130	116	75	17	338
Finance, insurance	3.51%	147	116	45	24	332
Education	2.47%	52	91	77	14	234
Accommodation	2.09%	73	77	39	9	198
Recreation activities	1.95%	75	58	35	17	185
Real estate	1.81%	71	60	27	13	171
Social work	1.73%	41	68	42	13	164
Water & electricity supply	1.43%	41	41	37	16	135
Waste management	1.07%	26	38	29	8	101
Oil and gas	0.58%	20	19	13	3	55
Total	100%	3351	3340	2047	729	**9467**

Finally, Figure 21 below offers a summary of Table 11 and Table 12 by showing the distribution of companies both per sector and firm size.

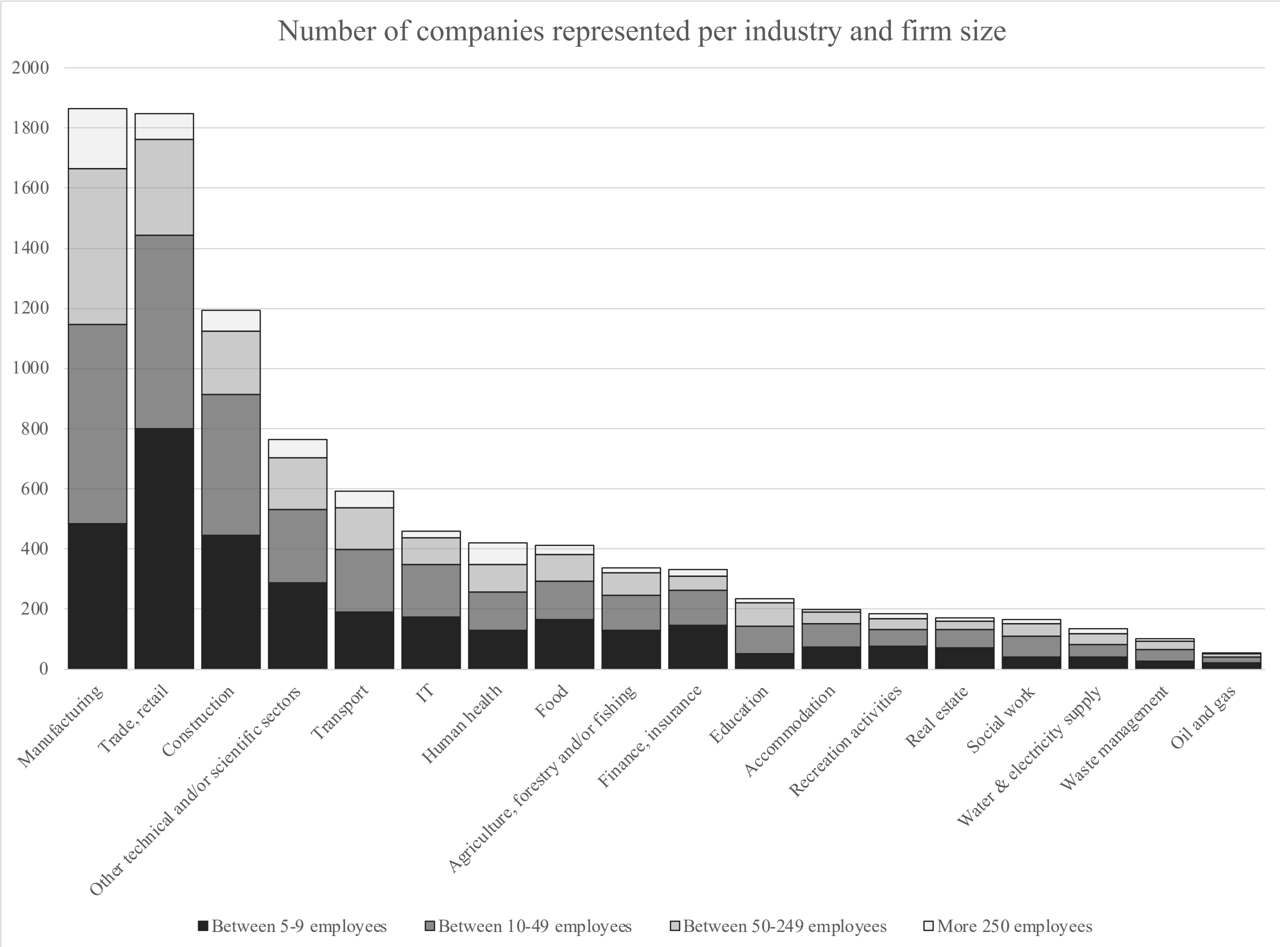


Figure 21. Sample description: industry and size distribution

2.3.3 Core variables

Regarding the variables of interest, the analyses focus on two main questions: first, digital technology adoption and, second, environmental innovation. The question related to digital technologies was stated as follows:

I will now name some digital technologies used by firms. Please indicate whether your firm currently uses any of them?

1. *Yes, we use it*
2. *No, we don't use it*
3. *We have plans to use it in the next 2 years*
4. *It is not relevant for our business*

Table 13 here below depicts the different technologies included in the survey.

Table 13. Selection of digital technologies variables from initial survey

Technologies included in the survey	**Examples provided**	**Selected variables**
Management Information Systems	*Enterprise Resource Planning, Customer Relationship Management, or HR Management Systems*	-
Cloud Computing/Cloud Storage	*Infrastructure or Software as a Service*	**Cloud computing**
Collaborative Platforms	*Videoconferencing or collaboration software like Zoom, SharePoint or Google docs*	-
Transaction Platforms	*Online marketplaces or sharing economy platforms (such as car-sharing)*	-
Audiovisual/Immersive Technologies	*Augmented Reality, Virtual Reality or satellite imaging*	**Immersive technologies**
Internet of Things	*Connected Devices using Sensors*	**Internet of Things**
Smart Robotics	*Autonomous vehicles, assembly robots or delivery drones*	**Smart robotics**
Artificial Intelligence	*Machine or Deep Learning, Optimization and Forecasting, Voice/Image Recognition, Natural Language Processing, Neural Networks or Big Data*	**Artificial intelligence**

The analyses will document the adoption rates at the level of each specific technology. The objective is to focus on digital technologies similar to Montresor & Vezzani (2022). As emphasized in Montresor & Vezzani (2022), the selection of technologies is not univocal, and relevance for the sustainability paradigm may be heterogeneous. They consider the Internet of Things, along with Big Data, to be among the most typical digital technologies of the fourth industrial revolution, based on Dalenogare et al. (2018). Next to this paper, the systematic review of the literature at the nexus between Industry 4.0 and sustainability conducted by Khan et al. (2023) also highlighted a series of technologies like additive manufacturing, artificial intelligence, artificial vision, big data, advance analysis, cybersecurity, Internet of Things, robotics, virtual and augmented reality (Jabbour et al., 2018; Laskurain-Iturbe et al., 2021; C. Zhang & Chen, 2020). The authors argue that these technologies have gained research interest in recent times and that they have provided various benefits to organizations (Oztemel & Gursev, 2020). They also state that studies looking at Industry 4.0 innovations with sustainability implications have focused on manufacturing and that Industry 4.0 is often associated with smart manufacturing. However, the authors emphasize that a number of studies look at such relationships in other sectors rather than manufacturing, and that this situation leaves space for further research in the electrical and electronic equipment or the pharmaceutical sectors. Indeed, these sectors may also use technologies under the Industry 4.0 umbrella and put them at the service of environmental innovation.

Based on this previous work which highlights relevant technologies and areas for future research, this chapter will focus on a subset of digital technologies: cloud computing, immersive technologies, Internet of Things, smart robotics and artificial intelligence (including Big Data).

Besides relying on a measure of adoption of each of these technologies, we also build a measure of what we call *Digital intensity*, which is again similar to Montresor & Vezzani (2022)'s investigations. We build this measure by summing up the number of technologies being adopted by each firm and use this measure as a continuous variable in the analyses. Next to digital technologies, we also look at specific environmental innovation practices adopted by firms. Table 14 below provides the list of actions included in the survey.

What action/s has your firm already taken to reduce its environmental impact? Please select all that apply.

Table 14. Selection of environmental innovation variables from initial survey

Environmental management practices included in the survey	Selected variables
We have optimised our processes	**Process innovation**
We have compensated for our impact (e.g. by planting trees, carbon credits etc.)	-
We have guidelines to encourage environmentally conscious behaviours (e.g. sustainable transport)	-
We have measured our impact	-
We have redesigned our products or services	**Product innovation**
We have changed our supply chain (e.g. greener suppliers)	-
We have radically changed our business model (e.g. by adopting a zero-waste approach)	**Business model innovation**

As our objective is to investigate specifically the relationships between digital technologies and environmental innovation, we will focus on a subset of actions by only keeping innovation-related practices at the level of processes, products/services and business models. As emphasized by Khan et al. (2023), most studies today focus on process, product, and business model innovations. We aim to contribute to those studies by using a unique dataset, which will enable us to investigate the relationships between digital technologies and these specific environmental innovation areas. In other words, we are particularly interested by the following three practices included in the survey: optimization of processes, redesign of products/services and radical change of business model practices that we use as a measure of process innovation, product innovation and business model innovation.

Based on the number of environmental innovation efforts performed (i.e. the sum of process, product and/or business model innovation dummies), we build a measure of environmental intensity that will also be included in the analyses.

2.3.4 Control variables

To account for potential industry fixed effects, we include dummies for each industry represented in the sample. In total, 18 industries are represented in the data. To avoid multicollinearity in the analyses, the ICT industry is considered as the alternative dummy and therefore left out of the regressions.

Country-fixed effects follow the same strategy as industrial effects control. However, we grouped the countries into four regions to avoid categories too small in terms of observations. Therefore, we grouped countries in the different European regions, considering the Western region dummy as the alternative dummy in the regression analyses that follow. The grouping and related distribution are available in Table 18.

To account for the size of companies, we rely on a variable made of four categories from which we, again, build dummy variables. In total, we have four dummies representing the four categories or firms (i.e. 5-9 employees, 10 – 49 employees, 50 to 250 employees, 250+ employees). The smallest category, 5-9 employees, is considered as the alternative dummy in our analyses and is therefore left out of the regression.

To complement industry, region and size controls, we also include a variable accounting for the operating margin of firms. While this variable can be dependent on the industry itself, it also partially reflects choices of companies in terms of investments, notably in terms of R&D. While we are not able to account specifically for the R&D factor, using the operating margin measure enables to control for such investment choices in the analyses. Furtermore, controlling for operating margin enables us to account for firms' productivity, which may partially influence technology and innovation choices.

It is worth noting that this measure is based on data available in ORBIS. It is obtained by dividing Profit & Loss Before Taxes of the most recent year available at the time of the survey (2020) by the turnover of this specific year (2020). To perform this calculation, non-valid numbers, NAs or missing observations needed to be dropped out of the datasat. Then, we exclude operating margin results above 1 as this also reflect irregularities in the ORBIS data. Following this data cleaning step, the final dataset used in the remaing part of this chapter is reduced to 6,443 observations in total.

Detailed descriptive statistics are available in Table 15 below. Moreover, a correlation matrix table that includes our core variables can be found in Table 19 in the appendix.

Table 15. Chapter 2 : summary statistics of variables of interest and control variables

	count	mean	std	min	25%	50%	75%	max
Cloud computing	6443	0.61	0.49	0	0	1	1	1
Immersive technologies	6443	0.15	0.35	0	0	0	0	1
Internet of Things	6443	0.4	0.49	0	0	0	1	1
Smart robotics	6443	0.08	0.27	0	0	0	0	1
Artificial intelligence	6443	0.09	0.28	0	0	0	0	1
Digital intensity	6443	1.32	1.11	0	0	1	2	5
Process innovation	6443	0.71	0.45	0	0	1	1	1
Product innovation	6443	0.4	0.49	0	0	0	1	1
Business model innovation	6443	0.21	0.4	0	0	0	0	1
Environmental innovation intensity	6443	1.32	0.95	0	1	1	2	3
Central and Eastern Europe	6443	0.34	0.47	0	0	0	1	1
Northern Europe	6443	0.23	0.42	0	0	0	0	1
Southern Europe	6443	0.28	0.45	0	0	0	1	1
Western Europe	6443	0.14	0.35	0	0	0	0	1
Accommodation	6443	0.02	0.14	0	0	0	0	1
Agriculture, forestry and/or fishing	6443	0.03	0.18	0	0	0	0	1
Construction	6443	0.12	0.32	0	0	0	0	1
Education	6443	0.01	0.12	0	0	0	0	1
Finance, insurance	6443	0.03	0.17	0	0	0	0	1
Food	6443	0.04	0.2	0	0	0	0	1
Human health	6443	0.04	0.19	0	0	0	0	1
ICT	6443	0.05	0.21	0	0	0	0	1
Manufacturing	6443	0.22	0.42	0	0	0	0	1
Oil and gas	6443	0.01	0.08	0	0	0	0	1
Other technical and/or scientific sectors	6443	0.08	0.28	0	0	0	0	1
Real estate	6443	0.02	0.13	0	0	0	0	1
Recreation activities	6443	0.02	0.13	0	0	0	0	1
Social work	6443	0.01	0.11	0	0	0	0	1
Trade, retail	6443	0.2	0.4	0	0	0	0	1
Transport	6443	0.06	0.25	0	0	0	0	1
Waste management	6443	0.01	0.11	0	0	0	0	1
Water & electricity supply	6443	0.02	0.12	0	0	0	0	1
Between 5-9 employees	6443	0.32	0.47	0	0	0	1	1
Between 10-49 employees	6443	0.35	0.48	0	0	0	1	1
Between 50-249 employees	6443	0.23	0.42	0	0	0	0	1
250 employees or more	6443	0.09	0.29	0	0	0	0	1
Operating margin	6443	-0.28	9.79	-494.38	0.01	0.04	0.09	1

2.4 Results

2.4.1 Descriptive analyses

2.4.1.1 Adoption of digital technologies

Figure 22 below depicts the adoption rates of the different technologies as well as the relationship with firm size. It can be observed that the most adopted technology is cloud computing, including cloud storage (61%). This technology is followed by Internet of Things (40%), described in our survey as connected devices that include sensors. The three technologies at the bottom of this list are immersive technologies, including augmented or virtual reality (15%), artificial intelligence (9%), and smart robotics (8%).

Looking at the different categories of firm size, it can be seen that adoption of digital technologies goes hand in hand with the number of employees. This observation is valid for the five technologies investigated in this chapter and is in line with previous research, such as McElheran et al. (2022) regarding AI, and Montresor & Vezzani (2022) concerning AI and other technologies like the Internet of Things.

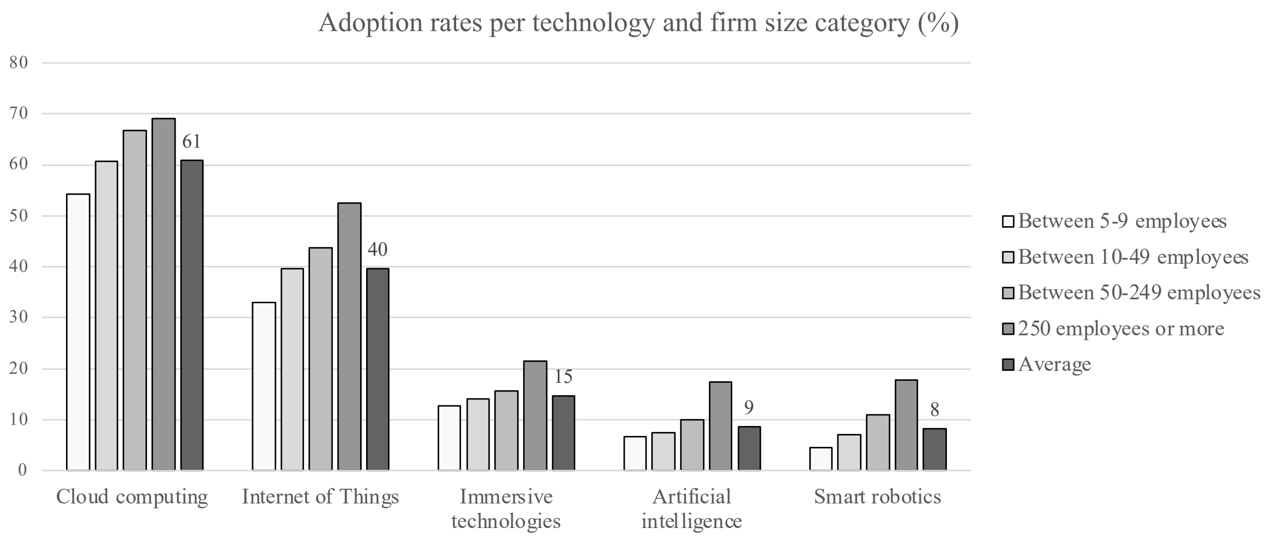


Figure 22. The relationship between digital technologies' adoption and firm size

2.4.1.2 Adoption of environmental innovation

Similarly to the study of digital technologies' adoption, we will now turn to environmental practices. Before looking at the specific set of actions, it is worth noting, based on another question included in the survey, that only 3% of firms stated that they are not environmentally aware at all. When asked about the magnitude of their efforts and objectives, 31% of the interviewed firms stated that they do not have concrete objectives to reduce their environmental impact, while 36% state that their objective is to marginally reduce their environmental footprint. The remaining firms, around 29% of the whole sample, declared that their objective is to radically reduce their environmental impact.

Looking at the specific actions that firms take to reduce their impact, Figure 23 shows that the optimization of processes is the most adopted innovation, with 71% of firms declaring that they have adopted it. Process innovation is followed by product innovation, with 40% of firms engaging in such efforts. At the bottom of this list, we find innovations at the level of business models, with 21% percent of firms declaring they have radically changed their business model approach.

Again, it is worth looking at the intersection between environmental innovation and firm size. Our results show similar patterns as Montresor & Vezzani (2022) as they did in the case of digital technologies' adoption. Indeed, the bigger the firm, the higher the likelihood of enaging in environmental innovation efforts. A small difference can be observed, however, when it comes to business model innovation, where we can see that firms below 250 employees show similar patterns, while the difference seems more visible for firms that have more than 250 employees.

Finally, it is also interesting to note that 23% of firms have not adopted any of the three environmental innovations tackled in this chapter (i.e. process, product or business model innovation).

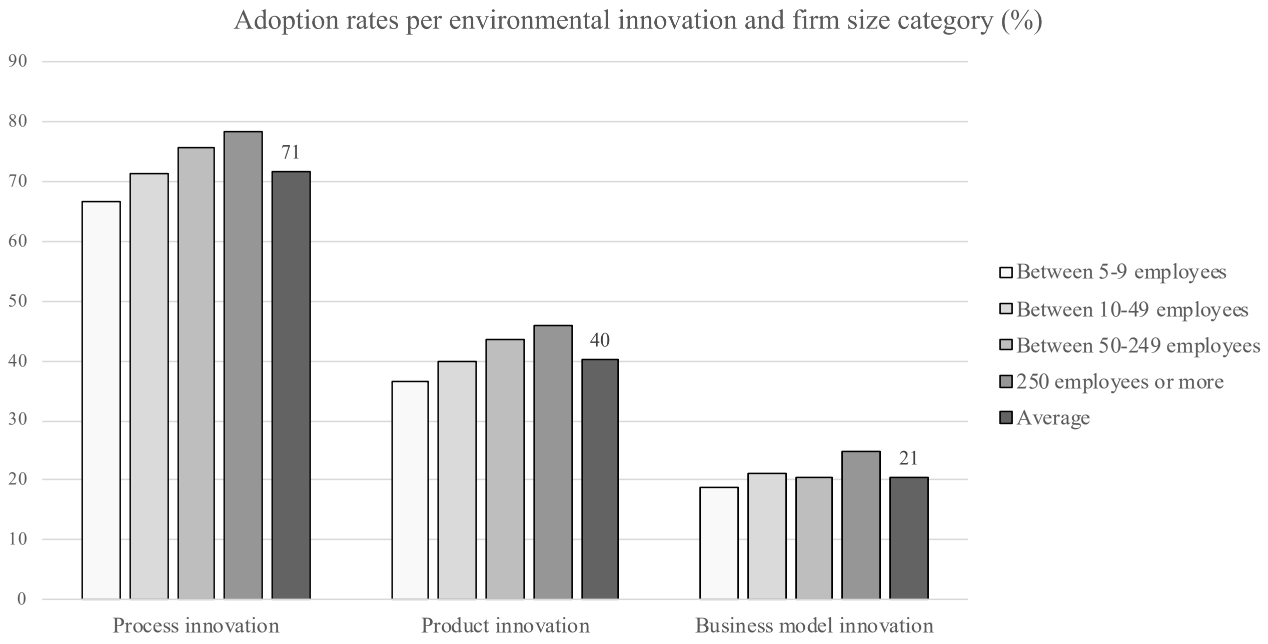


Figure 23. The relationship between the adoption of environmental innovations and firm size

2.4.2 Regression analyses

The objective of this second part of the analyses is to explore relationships between the adoption of digital technologies and environmental innovation efforts. Causality claims are not in the scope of the present chapter, as we aim only to document the potential joint presence of digital technologies and environmental innovation. Even though the ambition is not to identify the causal nature of the relationships, a first question we may ask concerns the direction of the relationship between digital technologies and environmental practices. This question was openly raised in our survey under the following terms:

To what extent do you agree or disagree with the following statements about digital technologies and environmental actions?

1. Using digital technologies has accelerated our environmental actions
2. Our environmental actions have accelerated the use of digital technologies

Firms were asked to answer this question with the following Likert scale:

1. Strongly agree
2. Somewhat agree
3. Somewhat disagree
4. Strongly disagree
5. Don't know

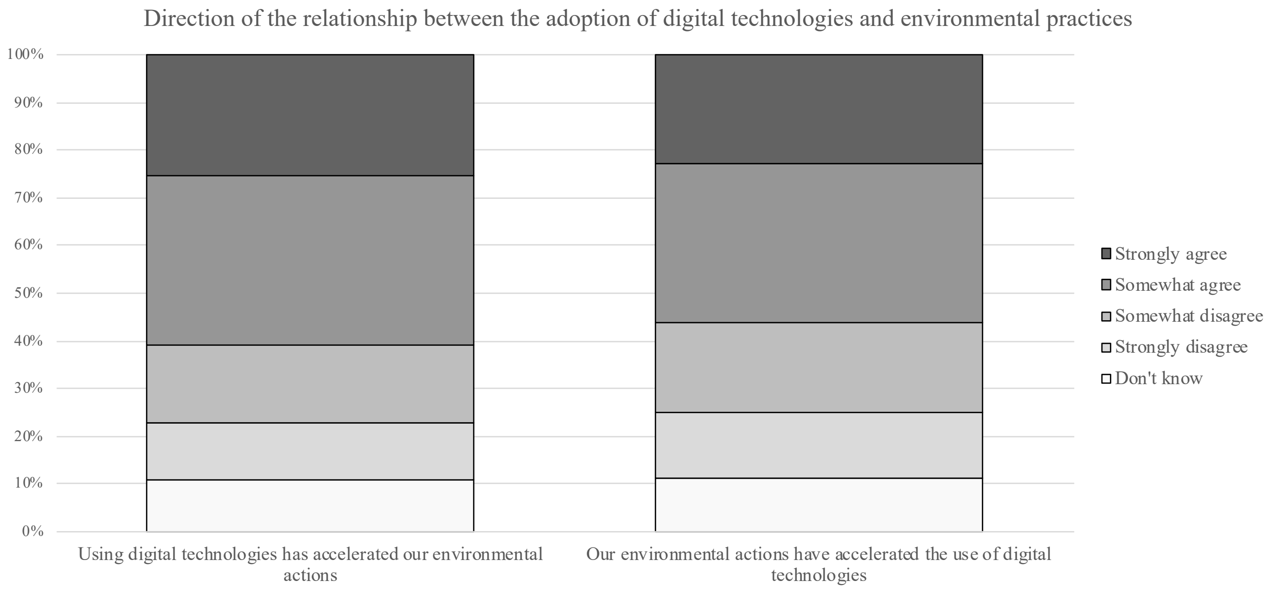


Figure 24. The adoption of digital technologies and environmental practices : direction of the relationship

In regard to Figure 24, it is worth noting that a majority of firms claim a causal link between the adoption of digital technologies and environmental actions, whatever the direction of the relationship. Looking closely at the direction of the relationship, we see that there is no straight-forward direction that can be drawn from these self-declared data. The proportion of firms agreeing with the propositions is slightly more important for the first option, considering that 61% of firms claim that the adoption of digital technologies has accelerated environmental actions, compared to 56% claiming the opposite. Therefore, we will focus the analyses on the regressions considering digital technologies as the independent variable. As potential complementarities can be bi-directional (e.g. Brynjolfsson & Milgrom, 2012), respondents were offered the possibility to agree on both options. However, future research could assess more closely the potential direction of the relationship between digital technologies and sustainability choices and actions, in order to better grasp triggering factors of both technology adoption and environmental actions.

To further explore the relationships between digital technologies' adoption and environmental innovation, we rely mostly on OLS model. Starting with the investigation of the relationship between digital technologies and environmental intensity, the first equation can be written as follows:

$$Environmental\ innovation\ (intensity) = \alpha + \beta Digital\ technology + Controls + \varepsilon$$

Controls include the region, industry, firm size and operating margin, as already depicted in the previous section. Regarding digital technologies, we look both at digital intensity as well as the level of specific technologies. In the first model, we include our measure of digital intensity, which represents the sum of digital technologies adopted. In the second model, we include each specific technology and look at the relationship with environmental intensity. For the sake of validity, and since we have a discrete categorical dependent variable, we also ran an ordered logit model and compare the overall observations with the OLS model.

In general, we are interested by the β value of each regression depicted in the table below. From the results shown in Table 16 below, we observe a positive and significant relationship between digital technologies' adoption and environmental intensity. In other words, the more technologies are adopted by the firm, the more environmental innovation efforts will be taken. This result is confirmed by the ordered logit model. Looking now at the coefficient specific to each technology, it can be seen that these are all positive and significant. However, some heterogeneity may be observed. Based on t-tests assessing the equality of coefficients, it is worth emphasizing that Internet of Things technologies correlate significantly more with environmental intensity than any other technology. The results of these tests are available in Table 20 in the appendix.

Table 16. Regression analysis between digital technologies' adoption and environmental innovation intensity

Dependent variable	Environmental innovation intensity			
Regression model	OLS	OLS	Ordered Logit	Ordered Logit
	(1)	(2)	(3)	(4)
Digital intensity	0.251***		0.525***	
	(0.010)		(0.022)	
Cloud computing		0.253***		0.559***
		(0.024)		(0.050)
Immersive technologies		0.206***		0.423***
		(0.033)		(0.068)
Internet of Things		0.343***		0.704***
		(0.024)		(0.050)
Smart robotics		0.153***		0.297***
		(0.042)		(0.085)
Artificial intelligence		0.170***		0.355***
		(0.042)		(0.086)
Operating margin control	Yes	Yes	Yes	Yes
Industry, region, and size dummies	Yes	Yes	Yes	Yes
Observations	6,443	6,443	6,443	6,443
R^2	0.114	0.117		
Adjusted R^2	0.111	0.113		
Residual Std. Error	0.899 (df=6417)	0.898 (df=6413)	1.000 (df=6415)	1.000 (df=6411)
F Statistic	33.015*** (df=25; 6417)	29.361*** (df=29; 6413)	(df=28; 6415)	(df=32; 6411)
Note:				*p<0.1; **p<0.05; ***p<0.01

The objective of the second part of the regression analyses is to further investigate these relationships, looking now at specific types of environmental innovations to assess whether the presence of certain technologies is more associated with certain types of innovation than others. To do so, we rely on a Linear Probability Model, which enables us to ease the interpretation of estimated marginal effects (Horrace & Oaxaca, 2006; McGarry, 2000). The overall robustness of the results and conclusions will be assessed based on Probit model.

In general, we are again interested by the β sign, value and significance in each regression depicted Table 17 below. To interpret this value, we divided the coefficient by the mean of the dependent variable. This enables us to compare relatively the magnitude of the coefficients across the regressions to the dependent variable. As a result, looking at the regression coefficients gives the percentage point changes associated with a change from 0 to 1 in the dummy independent variable, while dividing it by the mean of the dependent variable provide us changes in percentage, enabling us to compare with more objectivity the differences in the magnitude of change across dependent variables and across different types of environmental innovations. These relative coefficients can be found in *italic*, right below the original coefficients.

When it comes to digital intensity, it can be observed that it positively and significantly correlates with the three types of innovations. Looking closely at the technology, heterogeneity across technologies and innovations are worth noting. First of all, it can be observed that Internet of Things clearly show a transversal positive and significant relationship with environmental innovation, be it in terms of process (0.139, therefore 13.9 percentage point), product (0.121) or business model (0.083). This observation also holds for immersive technologies. However, it can also be seen that cloud computing correlates positively and signifcantly with process (0.161) and product innovation (0.082), but not with business model innovation. Finally, although adoption rates of smart robotics and artificial intelligence are similarly less than 10%, the heterogeneity across these two technologies when it comes to their relationship with environmental innovation is striking. It can be observed from the regressions below that smart robotics correlates positively and significantly with process (0.081) and product innovation (0.046), but not with business model innovation. This result is different for artificial intelligence, which correlates positively and significantly with product innovation and business model innovation, but does not correlate with process innovation.

Looking now at the relative effects, with respect to the dependent variable (meaning dividing the coefficients by the mean of the dependent variable i.e. average adoption rate), it can be seen that the relationship regarding Internet of Things and environmental innovation is stronger for business model innovation than for process innovation. Concretly, the regression results suggest a 40% increase in business model innovation when Internet of Things is also in place in the organization, while the marginal effect is of 19% for process innovation.

The same result holds for immersive technologies as well as artificial intelligence, which respectively show a 24% and 30% increase in the probability of business model innovation when these technologies are adopted. However, while immersive technologies correlate positively and significantly, as seen with Internet of Things and the three scopes of environmental innovation, the results suggest that artificial intelligence is not significantly associated with innovation at the level of processes. Indeed, the coefficient is low both in magnitude (1%) and significance.

Overall, these results shed light on the potential specificities of each technology in supporting environmental innovation efforts, confirming the supposed wide-spread role of Internet of Things and suggesting that smart robotics can have more local impact at the level of processes, while artificial intelligence looks present in organizations engaging in more disruptive innovation at the business model level. These observations are discussed into more details in the next section and results based on Probit models are available in Table 21 in the appendix.

Table 17. Regression analysis between digital technologies adoption and scopes of environmental innovation

Dependent variable	Process innovation	Process innovation	Product innovation	Product innovation	Business model innovation	Business model innovation
Regression model	OLS	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
Digital intensity	0.109***		0.094***		0.048***	
	(0.005)		(0.005)		(0.005)	
Cloud computing		0.161*** *0.22*		0.082*** *0.20*		0.010 *0.05*
		(0.012)		(0.013)		(0.011)
Immersive technologies		0.064*** *0.09*		0.091*** *0.22*		0.051*** *0.24*
		(0.016)		(0.018)		(0.015)
Internet of Things		0.139*** *0.19*		0.121*** *0.30*		0.083*** *0.40*
		(0.012)		(0.013)		(0.011)
Smart robotics		0.081*** *0.11*		0.046** *0.11*		0.026 *0.12*
		(0.020)		(0.022)		(0.019)
Artificial intelligence		0.009 *0.01*		0.098*** *0.24*		0.062*** *0.30*
		(0.020)		(0.022)		(0.019)
Operating margin control	Yes	Yes	Yes	Yes	Yes	Yes
Industry, region, and size dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,443	6,443	6,443	6,443	6,443	6,443
R^2	0.098	0.107	0.065	0.067	0.028	0.031
Adjusted R^2	0.095	0.103	0.062	0.062	0.024	0.027
Residual Std. Error	0.430 (df=6417)	0.428 (df=6413)	0.475 (df=6417)	0.475 (df=6413)	0.399 (df=6417)	0.399 (df=6413)
F Statistic	27.935*** (df =25; 6417)	26.380*** (df =29; 6413)	17.944*** (df =25; 6417)	15.778*** (df =29; 6413)	7.466*** (df= 25; 6417)	7.185*** (df= 29; 6413)
Note:						*p<0.1; **p<0.05; ***p<0.01

2.5 Discussion

This chapter has first shown that the most pervasive technologies include cloud computing and Internet of Things, while artificial intelligence and smart robotics are adopted by less than a tenth of European companies.

On the sustainability side, we observed that the optimization of processes is the most adopted innovation. At the bottom of the list of possible environmental innovation areas, we found that the radical change of business model is the least adopted environmental innovation scope.

These results suggest that European firms are still mainly focusing on (and struggling with) relatively "old" technologies, far from mainstream adoption of more frontier tools like AI. Furthermore, they are only starting to scratch the surface of sustainability by working on optimization of existing processes rather than rethinking business models. Consistent with many earlier findings from the literature (e.g. McElheran et al., 2022; Montresor & Vezzani, 2022), we find that larger firms are faster on average at adopting technologies and conducting environmental innovation efforts.

In a second step, relationships between digital technologies and environmental innovations are investigated. Thanks to granular data at the level of technologies and environmental innovations, we are able to complement recent studies like Montresor & Vezzani (2022) by distinguishing several technologies and scopes of innovation (i.e. process, product and business model). While in general, our results confirm previous studies like Cainelli et al. (2012) and Montresor & Vezzani (2022) in showing digital technologies' adoption positive correlation with environmental innovation and its intensity of diffusion in processes, products and/or business models, heterogeneity could be observed at the level of specific technologies and scopes of innovation.

Indeed, the results confirm the more transversal role that the Internet of Things could play in terms of sustainability efforts, as it is positively associated with the three scopes of innovations tackled in this chapter, and this observation is also valid for immersive technologies.

However, cloud computing, smart robotics and AI exhibit different patterns. While smart robotics and AI have the same adoption rates, it could be observed that their relationships with specific types of environmental innovations differ. Indeed, even though they are both associated with product innovation, it seems that the impact of smart robotics could be found at the level of processes, while AI appears to be more present with business model-related innovations. This observation supports arguments in favor of AI being an Invention in the Method of Invention itself (Griliches, 1957), driving more profound and systemic change within organizations, while smart robotics could support the optimization of business as usual at the process level. When it comes to cloud computing, it is, like smart robotics, also more associated with process and product-related innovations.

As explained throughout this chapter, this relationship can go in both directions and we do not claim any causal relationship with a clear direction. Indeed, complementarities can be bi-directional (W. Zhang & Rai, 2021) and system-wide change can also be considered as a pre-requisite to AI adoption, as indicated recently by Agrawal et al. (2023), but also as an effect of it, as it is intended to serve a new general-purpose “method of invention” (Cockburn et al., 2018). Uncovering the direction of these relationships is out of reach with our data, but it seems to be of paramount importance. If environmental innovation drives the adoption of frontier technologies, then policies aimed at fostering advanced digitalization need to also look at sustainability as a key driver of adoption. In return, if more advanced technologies are a key enabler of more impactful environmental practices, then sustainability policies need to simultaneously encourage the adoption of advanced digital technologies.

Finally, it is worth noting that the patterns we observe may be due to a common latent factor, which would relate to the maturity and transformational ability of firms, which is necessary to adopt both types of practices. Therefore, for both digital and green policies, it will be crucial to firms' ability to embrace more radical change and transformation, which will require massive investments in organizational learning and capital rather than in technologies and techniques. According to some sources like McPhearson et al. (2021), the environmental challenges the world is facing require us to holistically rethink our whole systems and models. Business model innovations include, for example, the transition towards zero-waste approaches or circular models. Examples of such business model practices include the use of connected sensors (e.g. Internet of Things) to better understand consumption patterns or track products' material information, thereby supporting the transition towards circular models. Besides that, other examples of radical changes at the business models level include subscription- (or access-) based models that rely on advanced data services supported by AI technologies.

Our results show that the joint presence between specific types of technologies (e.g. AI) and business model innovation is a reality. Is this joint presence effectively leading to less impactful activities? This question offers new avenues of research at the nexus between digital technologies and environmental management.

2.6 Conclusion

Although based on self-declared, cross-sectional survey data, our efforts to disseminate facts on the adoption of digital technologies and environmental innovation are important for our understanding of the *twin transition* and how firms are currently coping with it. This chapter provides quantitative insights on the associations between digital technologies and sustainability at the level of firms. More specifically, these results refine our understanding of the relationships between specific technologies and specific scopes of environmental innovations. By doing so, it aims to serve as basis for future research on the complementarities between digital technologies and environmental management.

In terms of contribution, this chapter brings insights for both academics and practitioners. The results contribute to an emerging research field at the nexus between digital technologies and sustainability. By documenting and exploring relationships between the adoption of digital technologies and environmental innovation, it opens doors for future work on complementarities between the two topics. It is worth emphasizing that firms are still experimenting with the integration between their digital and sustainability transformations.

While we provide initial evidence of mutual presence of digital technologies and environmental management efforts while also highlighting differences across different technologies, it will be important to assess performance effects of such associations in financial and environmental terms. Next to further exploring these complementarities and impacts on firms' performance, research under the lens of organizational constructs and strategic management are needed to further guide the private sector in the transformations they operate, making sure their digital transformation and the adoption of digital technologies also supports rather than undermines their sustainability efforts.

Finally, our results are useful for policy makers. As said in the beginning of the chapter, the integration between digital and environmental issues is high on political agendas. However, refined knowledge is needed on this integration and current experimentation by firms. This chapter provides unique large-scale evidence regarding the presence of both digital technologies and environmental management practices across firms' size, industries, and geographies. It is crucial for policymakers to better grasp the specifies of the different types of technologies used by companies today and the various impacts they may have on sustainability issues. A better understanding of how firms adopt specific technologies and practices is crucial for guiding policymakers in their efforts to direct technological changes towards uses that positively contribute to the economy, society and environment.

2.7 Appendix

Appendix A : variables description

Table 18. Appendix A.1 : Regional grouping and distribution

Region	Country	Count
Central and Estearn Europe	Bulgaria	415
	Croatia	216
	Czech Republic	346
	Hungary	284
	Poland	453
	Romania	424
	Slovakia	261
	Slovenia	229
	Sub-total	**2628**
Northern Europe	Denmark	417
	Estonia	270
	Finland	403
	Latvia	273
	Lithuania	213
	Sweden	414
	Sub-total	**1990**
Southern Europe	Cyprus	51
	Greece	342
	Italy	650
	Malta	25
	Portugal	394
	Spain	447
	Sub-total	1909
Western Europe	Austria	365
	Belgium	428
	France	601
	Germany	605
	Ireland	280
	Luxembourg	120
	Netherlands	541
	Sub-total	2940
Total		**9467**

Appendix B : correlation matrix

Table 19. Appendix B.1 : Correlation matrix between variables of interest

		1	2	3	4	5	6	7	8	9	10
1	**Cloud computing**	1									
2	**Immersive technologies**	0.17	1								
3	**Internet of Things**	0.23	0.2	1							
4	**Smart robotics**	0.11	0.11	0.15	1						
5	**Artificial intelligence**	0.16	0.2	0.17	0.18	1					
6	**Digital intensity**	0.66	0.56	0.68	0.44	0.51	1				
7	**Process innovation**	0.24	0.12	0.21	0.11	0.08	0.28	1			
8	**Product innovation**	0.14	0.12	0.17	0.07	0.11	0.22	0.31	1		
9	**Business model innovation**	0.05	0.08	0.12	0.05	0.08	0.13	0.2	0.23	1	
10	**Environmental intensity**	0.2	0.15	0.24	0.11	0.13	0.3	0.72	0.76	0.64	1

Appendix C : t-test results

Table 20. Appendix C.1 : results of OLS regression coefficients' tests of equality (t-test)

t-tests, equality of coefficients p-value results		1	2	3	4	5
1	Internet of Things	-	-	-	-	-
2	Cloud computing	0.015	-	-	-	-
3	Immersive technologies	0.002	0.284	-	-	-
4	Smart robotics	0.000	0.040	0.312	-	-
5	Artificial intelligence	0.000	0.088	0.486	0.800	-

Appendix D : robustness checks

To assess the robustness of the results, we compared the results from the Linear Probability model used in the previous section with the results from the Probit model. Probit is an alternative to the Linear Probability Model we decided to rely on for interpretation purposes. As shown by Table 21 below, the same conclusions hold using this model, meaning that Internet of Things and immersive technologies correlates positively and significantly with all types of environmental innovation, which is not the case for cloud computing, smart robotics and artificial intelligence. It can be observed that cloud computing and smart robotics correlates with process and product innovation but not with business model innovation, while artificial intelligence correlates positively with product and business model innovation, but not with process innovation.

Table 21. Appendix D.1 : Core regressions using probit models

Dependent variable	Process innovation	Process innovation	Product innovation	Product innovation	Business model innovation	Business model innovation
Regression model	Probit	Probit	Probit	Probit	Probit	Probit
	(1)	(2)	(3)	(4)	(5)	(6)
Digital intensity	0.362***		0.230***		0.133***	
	(0.017)		(0.015)		(0.016)	
Cloud computing		0.455***		0.186***		-0.021
		(0.036)		(0.034)		(0.038)
Immersive technologies		0.236***		0.230***		0.152***
		(0.056)		(0.047)		(0.051)
Internet of Things		0.446***		0.308***		0.271***
		(0.038)		(0.034)		(0.038)
Smart robotics		0.357***		0.128**		0.092
		(0.077)		(0.060)		(0.065)
Artificial intelligence		0.038		0.227***		0.153**
		(0.070)		(0.059)		(0.063)
Operating margin control	Yes	Yes	Yes	Yes	Yes	Yes
Region, industry, and size dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,443	6,443	6,443	6,443	6,443	6,443
Residual Std. Error	1.000 (df=6418)	1.000 (df=6414)	1.000 (df=6418)	1.000 (df=6414)	1.000 (df=6418)	1.000 (df=6414)
F Statistic	(df=24; 6418)	(df=28; 6414)	(df=24; 6418)	(df=28; 6414)	(df=24; 6418)	(df=28; 6414)
Note:						*p<0.1; **p<0.05; ***p<0.01

3 Chapter 3: Integrating digital transformation and corporate sustainability: a conceptual strategic management framework

Digital transformation and sustainability are two major challenges impacting organizations today. However, there is a need to better understand how companies currently deal with such issues from a transformational and organizational perspective. In this chapter, I propose an overarching theoretical framework that integrates digital transformation and corporate sustainability under the lens of strategic management (Figure 25). The contribution of this chapter is threefold. First, it lays the groundwork for future research at the intersection between digital transformation and corporate sustainability by mapping key concepts, theories and their relationships. Second, it brings insights back to the industry and proposes guidance to incumbent firms. Third, it also informs policymakers on the status of such transformation. The integration between these two topics is high on policymakers' agenda, but besides anecdotal use cases or promising estimates on the enabling potential of digital technologies in terms of environmental sustainability, we still do not know much about how firms (should) manage such transformational programs.

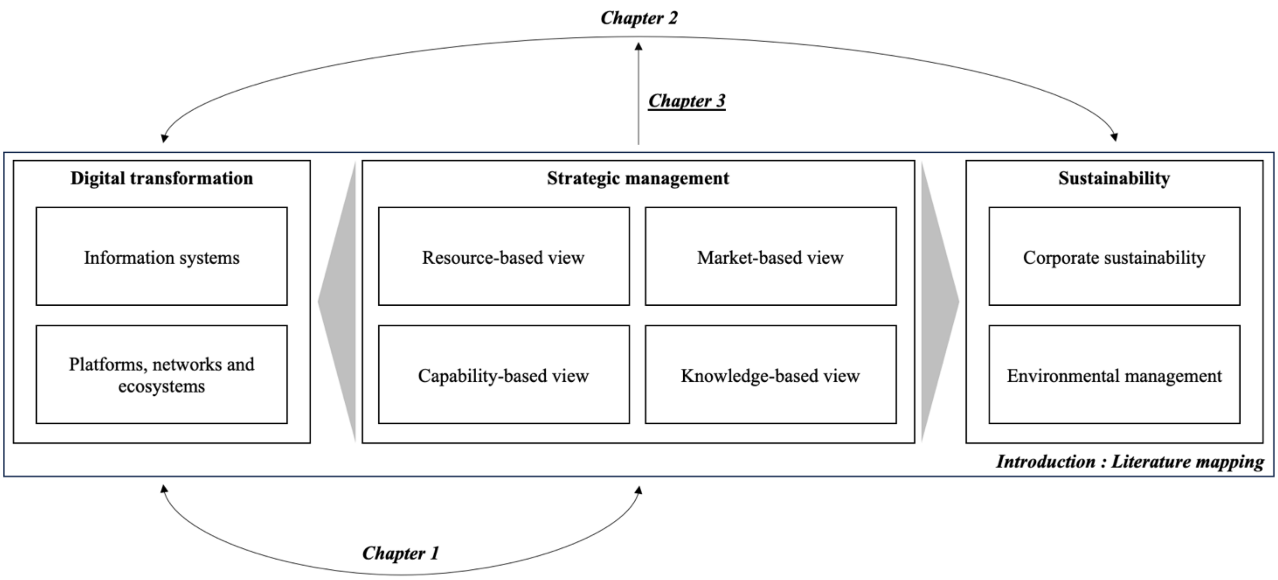


Figure 25. Literature mapping: third chapter contribution

3.1 Introduction

In the current context of digital transformation and sustainability imperatives, studies have emphasized the need for researchers to observe and bring insights back to the industry regarding the convergence of these two topics, notably within multinational firms (George et al., 2021b), as well as the need for such companies to become purpose-driven (George & Schillebeeckx, 2022). Although digital and sustainability issues and related transformations within organizations have been well studied separately, there have been few studies looking at the integration of such transformations into corporate strategy. For a few years, there have been calls from researchers to integrate perspectives and look at questions that lie at the intersection between both topics (e.g. Feroz et al., 2021; Guandalini, 2022). While the integration between digital and sustainability transformations is considered a priority by European policymakers and has begun to grasp the attention of industry leaders, a crucial question remains open to date:

How can multinational enterprises strategically integrate digital transformation with corporate sustainability?

This chapter aims to tackle this question and bridge the gap between the digital transformation and corporate sustainability literatures under the prism of strategic management and organizations. To do so, it adopts a theory building approach and develops a conceptual model as defined by Jaakkola (2020). Moreover, this chapter is based on interdisciplinarity, which is much needed to understand the relationships between digitalization and sustainability (Santarius et al., 2023). As a first step, it provides a thorough analysis of the current knowledge related to digital transformation and sustainability, leveraging recent reviews of the literature at the nexus between the two domains. By doing so, it aims to precisely identify the theoretical constructs of interest as well as the current gaps that need to be tackled in this emerging field of research. Subsequently, this chapter aims to design a conceptual model which will propose a guiding strategic and comprehensive framework that integrates concepts at the intersection between digital transformation and corporate sustainability, focusing on the environmental pillar of sustainability. In terms of contributions, it validates, reinterprets, extends, and integrates early theoretical propositions or concepts within a comprehensive strategic management framework that can serve as a basis for future research in the field. It also proposes an updated definition of the concept of *digital transformation* in line with corporate sustainability. In terms of practice, this chapter offers guidance to incumbent firms and an early overview of current mechanisms of integration observed on the field.

To reach its objectives, this chapter will be divided as follows: in the next section, a review of the existing literature on the intersection between digital transformation, sustainability and strategic management is presented, highlighting the main theoretical concepts and research gaps identified. The section that follows will describe the theory building methodology used, inspired by Jaakkola (2020). In terms of methodology, the theory building approach is complemented by qualitative data collected through interviews to improve the understanding of the model by practically illustrating its underlying concepts. Detailed findings from these interviews are available in Appendix B and will support the presentation of the conceptual framework that precedes the conclusion.

3.2 Theoretical background

Del Río Castro et al. (2021) and Brenner & Hartl (2021) confirmed that sustainability and digitalization are megatrends that reshape the economy and society. At the same time, 'sustainability,' as well as 'digital technologies,' are seen as disparate terms (George et al., 2021b) whose holistic character make a precise definition difficult (Osburg & Lohrmann, 2017).

As explained in the introduction of this thesis, Caputo et al. (2021) emphasize the fact that the term sustainability is difficult to define due to its multi- and transdisciplinary nature and its influence on socio-economic organizations at all levels, be it in terms of actions, decisions, and behaviors. The modern concept of sustainability emerged in the 70s and was popularized in the early 80s (Purvis et al., 2019) at a time when the public awareness was raised of the societal and environmental impacts of the different industrial revolutions. Despite the difficulty to align on a definition for 'sustainability,' there has been a common understanding of the initial concept of *sustainable development*, defined in the Brundtland report in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Passet (1979) initially suggested that behind the notion of sustainability lie in fact three interrelated pillars: the economy, the society, and the environment.

3.2.1 Sustainability and strategic management

The literature on firms' sustainability is vast (Bansal & Roth, 2000). However, the concept of sustainable development itself does not provide sufficient guidance for companies in terms of strategies, plans or activities (Baumgartner & Rauter, 2017). There is a rising interest in making businesses work towards what the literature calls corporate sustainability (Moon, 2007; Baumgartner, 2014). Dyllick & Hockerts (2002) definition of corporate sustainability is inspired by the definition of sustainable development reviewed above. They defined it as 'meeting the needs of a firm's direct and indirect stakeholders [...], without compromising its ability to meet the needs of future stakeholders as well.'

According to Salzmann et al. (2005), corporate sustainability is 'a strategic and profit-driven corporate response to environmental and social issues caused through the organization's primary and secondary activities.' Researchers in the strategic management field have been increasingly interested by the integration of corporate sustainability in a company's strategy, vision and culture (Stead & Stead, 2000; Jin & Bai, 2011). The interest of strategic management scholars lies in the strategy itself, which Mintzberg (1978) defined as a pattern in a stream of decisions.

As explained by Engert et al. (2016), there is not one unique definition of strategy or corporate strategy. Mintzberg (1987) stated that corporate strategy is about explaining the meaning and vision of the company to stakeholders while also defining the boundaries of corporate policies, thereby contributing to a better understanding of the identity and culture of the company.

Later on, Johnson et al. (2008) and Zhang et al. (2013) explained that corporate strategy is a combination of three elements: strategic analysis, choice and, finally, implementation. Hill & Jones (2008) stated that strategy formulation is about the analysis of a company's environment and the selection of corporate strategies, while strategy implementation is about putting the strategies into action. The literature of strategic management has looked at strategy formulation and implementation but also at the potential success factors. Two main perspectives exist in that matter: the market-based-view (MBV) (Porter, 1979), which considers firms' performance as dependent on the structure of the market (Engert et al., 2016), and the resource-based-view (RBV) (Barney, 1991), which considers internal resources as a key success factor. Even though the present chapter focuses more on internal success factors (i.e. RBV), the MBV and RBV should be seen as complementary rather than contradictory.

Today, companies lack a strategic approach regarding the integration of corporate sustainability into corporate strategy (Galbreath, 2009; Hahn, 2013). Several strategic management frameworks (e.g. Robèrt et al., 2002; Labuschagne et al., 2005; Zhang et al., 2013; Baumgartner, 2014) distinguish three levels for the integration of sustainability into corporate strategy: the normative, strategic, and operational levels. The normative level, based on corporate vision, policy, governance, and organizational culture (Bleicher, 1996), ensures the legitimacy of firms' activities by its stakeholders and society (Ulrich, 2001). The strategic level relates to the effectiveness and the reachability of long-term objectives (David, 2011), while the operational level ensures the strategy is efficiently implemented.

Engert et al. (2016) have summarized the existing knowledge at the intersection between corporate sustainability and strategic management in the following framework (see Figure 26 below) composed of three building blocks: organizational influences, internal and external drivers, and supporting or hindering factors. The authors emphasize gaps in the literature, such as the lack of studies on how strategy formulation and implementation related to corporate sustainability is carried out in practice. Therefore, they suggest that we should start focusing on how firms could integrate corporate sustainability into strategic management in practice.

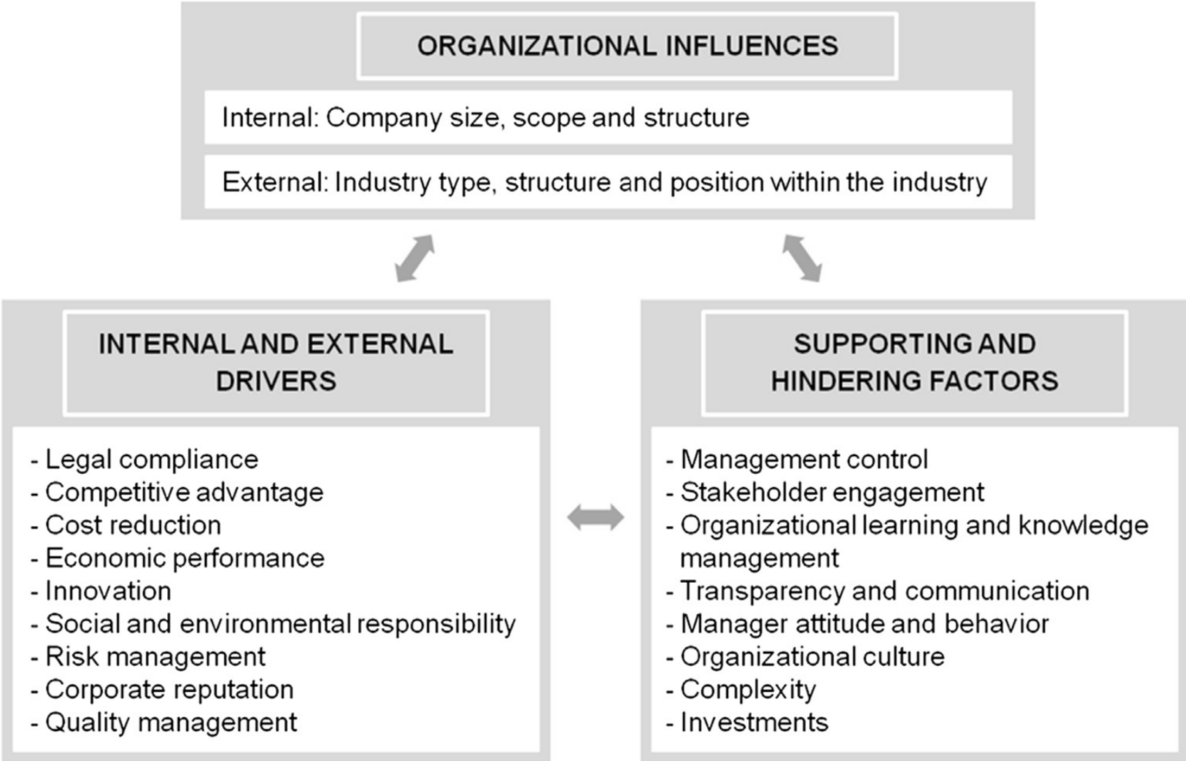


Figure 26. Organizational influences, internal/external drivers and supporting/hindering factors of the integration of corporate sustainability in corporate strategy (Engert et al., 2016)

It is worth noting that this study focuses on the environmental pillar of sustainability and therefore also considers the literature specifically related to environmental management. This field of research has been particularly interested by the study of what the literature calls environmental management practices (EMPs). EMPs are the techniques, policies and procedures used by a firm to monitor or control the impacts of its operations on the natural environment (Montabon et al., 2007).

These practices can be operational, tactical or strategic (Montabon et al., 2007). The motivation behind the adoption of such practices could either be reactive, such as in response to regulation or public pressure, or proactive, which aims for a more effective use of resources or improved reputation (Rondinelli & Vastag, 1996). When it comes to classifying such practices, González-Benito & González-Benito (2005) suggested that there exist three categories: organizational, operational, and communicational practices. As explained by Potrich et al. (2019), organizational practices are related to changes in firm-level environmental policies, including changes in procedures or environmental responsibilities. Operational practices usually target two core components of companies: products, and processes. Finally, as its name indicates, communicational practices aim at reporting and communicating pro-environmental actions adopted.

3.2.2 Digital transformation and strategic management

Sustainability has recently intersected with the diffusion of digital technologies. As explained in the introduction, the concept of 'digital transformation,' resulting from the profusion of digital technologies, exhibits the same complexity as sustainability in terms of definition. Guandalini (2022) indicates that the literature uses digitization, digitalization or digital transformation as inter-changeable terms (Gong & Ribiere, 2021). In this chapter, Gong & Ribiere (2021)'s unified definition of digital transformation is considered:

Digital transformation is "a fundamental change process enabled by digital technologies that aims to bring radical improvement and innovation to an entity [e.g., an organization, a business network, an industry, or society] to create value for its stakeholders by strategically leveraging its key resources and capabilities."

Rêgo et al. (2022) have recently offered a comprehensive review of the literature at the intersection between digital transformation and strategic management. They emphasized six clusters of research based on the stages of strategic management: external environment analysis (e.g. competition vs cooperation), internal environment analysis (e.g. organizational culture), strategy formulation (e.g. mission, goals and strategies), strategy implementation (e.g. actions and operational projects), strategy evaluation (e.g. real performance compared with defined goals) and, finally, feedback and learning (e.g. potential corrective actions or decisions regarding existing plans). Furthermore, the authors emphasized the fact that digital transformation and strategic management are closely linked to a redefinition of firms' vision and strategy, organization structure, processes, capabilities and culture. Such work at the intersection between digital transformation and strategic management will serve as a basis for the present chapter.

3.2.3 Digital transformation and sustainability

To date, the literature has recognized the potential of specific forms of digitalization towards the development of sustainability (e.g. Di Vaio et al., 2021; Saberi et al., 2019). For example, digital technologies could play a role in advancing sustainability by leading to efficiency gains and more sustainable production patterns (Paiola et al., 2021). In addition, innovation overall and digital innovation in particular is recognized as a vehicle for sustainability (Fagerberg, 2018), through the shared value created by knowledge management systems, openness of access, and organizational structure (Chaurasia et al., 2020). Other authors have suggested that digital technologies could contribute to sustainability goals by reducing cost, waste, information asymmetries, inequality, and risk of injury (Birkel & Müller, 2021). Practitioner studies have also emphasized the role such technologies can play, notably in terms of energy (e.g. energy efficiency, grid digital twin), materials (e.g. circularity) and mobility (e.g. Mobility as a Service), claiming that it could even reduce global CO_2e emissions by up to 20% (World Economic Forum, 2022).

This anecdotal evidence suggests that digital transformation could have enormous potential to drive toward a more environmentally sustainable world. At the same time, concerns have arisen on this simplistic perspective. As indicated earlier, the ICT industry itself is responsible for 2.1 to 3.9% (Freitag et al., 2021) of global greenhouse gas (GHG) emissions, a share similar to the one of the aviation sector. This impact is expected to drastically increase in the coming years, due to the potential rebound effects that may result from efficiency improvements, the inclusion of emerging technologies such as blockchain and Internet of Things, which are currently excluded from most estimates because they are not considered as ICT, and finally, the uptake of emerging technologies such as artificial intelligence, which have not yet demonstrated the ability to abate more impact than they generate (Freitag et al., 2021).

In this context, researchers have tried to frame the overall relationships between digital technologies and sustainability (Hilty & Aebischer, 2015). While in the industry there is an overall optimistic view about the opportunities that digitalization offers to sustainability, it is important to keep raising awareness on the fact that because digital transformation could be a disruptive force, it may also negatively affect sustainability outcomes if it is left unattended or uncontrolled (Flyverbom et al., 2019). Aksin-Sivrikaya & Bhattacharya (2017) emphasized the importance of developing sustainable governance models and here I will concretely review the specific research gaps I attempt to fill.

3.2.4 Research Gaps

Nowadays, firms are challenged to leverage digital technologies for sustainability imperatives, but they also face changing consumer preferences, stakeholder demands and waves of competition on top of radical changes in the global institutional fabric (Hwang & Höllerer, 2020). In other words, firms are required to re-invent themselves to seize the potential brought by digital innovation while, at the same time, tackling sustainability issues. In this context, there is a need to transform operations, products, business models as well as elements such as culture to integrate digital and sustainability transformations (e.g., Isensee et al., 2020 – focusing on SMEs).

However, as mentioned by some authors, the application of digital technologies for sustainability purposes is still insufficiently discussed in the academic literature (e.g. George et al., 2021). Researchers from various streams of the literature have therefore called for more integration between sustainability and digital transformation studies. Authors such as Seidel et al. (2017) have highlighted the need to consider sustainability in information systems (IS) research and emphasized the potential of IS notably in terms of sensemaking, decision making and knowledge creation (Butler, 2011) as well as in terms of automation (Dao et al., 2011) and innovation (N. P. Melville, 2010).

More recently, papers like (N. P. Melville, 2010) emphasized the fact that, due to the emergence of new digital technologies, digital transformation strategy profoundly changes the way organizations carry out operations, create business opportunities and tap into industry-wide collaboration. According to the authors, digital technologies are no longer only support systems, but they reshape business leaders' agendas and participate in a paradigm shift by radically changing the way firms create and capture value. Still according to these authors, there is a need in this context to integrate environmental sustainability into the digital transformation strategy.

Xia et al. (2022) confirm that studies exploring the digital transformation and environmental management relationships, alongside the theory that lies behind it, remain scarce. According to the authors, future research needs to explore the mechanisms by which digital transformation affects environmental management. Adding the notion of purpose and focusing on multinational enterprises, George & Schillebeeckx (2022) stated that this context offers the opportunity to generate empirical evidence regarding the drivers and contexts where such efforts are fruitful and are likely to lead to novel theoretical lenses and empirical approaches to the organizational design of multinational enterprises.

Gomez-Trujillo & Gonzalez-Perez (2022) also confirmed current research gaps at the intersection between digital transformation and sustainability. Like the previous papers mentioned, they emphasized the fact that the combination of sustainability and digitalization within firms' strategy requires structural transformations at the organizational level and regard to the new role a company should assume in its business ecosystem. This context requires changes in the strategy or business model, and a profound commitment to sustainability.

Finally, Guandalini (2022) confirms that there is currently a lack of guidance on this topic, and this situation requires particular attention. Indeed, tackling such questions could have practical implications for both regulators and practitioners, be it respectively in terms of policy development or effective strategy building. The second aspect raised by Guandalini (2022) related to strategy building is particularly important for this chapter. The goal of this work is based on the literature review at the nexus between corporate sustainability, digital transformation and strategic management, as well as on the different research gaps identified above, and intends to offer strategic guidance on the following question:

How can multinational incumbents strategically integrate digital transformation with corporate sustainability?

This chapter aims to contribute to the literature at the intersection between digital transformation and corporate sustainability by validating, reinterpreting, extending, and integrating early theoretical propositions through a comprehensive strategic management framework illustrated by empirical observations. This framework encompasses the organizational conditions and channels through which firms could exploit potential synergies between digital technologies and environmental sustainability. This overarching framework aims to provide a foundation for future research in the field while offering practical insights to guide practitioners and policymakers in designing the right incentives and conditions for a digital transformation aligned with sustainability (Gomez-Trujillo & Gonzalez-Perez, 2022).

In summary, and as suggested by Guandalini (2022), this chapter will tackle three specific areas. First, it focuses on managerial issues to answer the current need to guide companies in the implementation of such transformational and inter-related programs. Second, and to complete the first point, it adopts a strategic management perspective. As explicitly mentioned by Guandalini (2022), there is a lack of overarching strategic frameworks that prevents understanding of the phenomenon beyond specific use cases. The third and last area concerns the unit of analysis. Indeed, still confirmed by Guandalini (2022), there is a lack of studies at the organizational level that look at how business or government organizations, including stakeholders and functions, can exploit the synergies between their digital transformation and sustainability objectives. This could favor the development of practical research, applicable to a wider variety of contexts and actionable by these organizations. The next section details the research design adopted to answer the research question and tackle the research gaps highlighted here before presenting the conceptual framework.

3.3 Research design

3.3.1 Methodology

The conceptual framework developed in this chapter is based on a conceptualization and theory building approach and, more precisely, a model-based approach (Jaakkola, 2020). This approach is complemented by empirical data intended to provide early insights on current practices associated with the concepts used throughout the developed framework and improve its understanding.

Conceptual research is different from pure empirical work in the sense that, in the first case, authors need to justify the choice of previously developed theories and concepts, while in the latter, the research explains which data, sampling strategy and research instruments are needed to tackle certain research questions. Jaakkola (2020) illustrates the distinctions between research design elements in empirical work and conceptual work the translation of a certain phenomenon into a conceptual language and an approach that integrates concepts. As indicated by the author, the purpose of conceptual papers is to propose new relationships among constructs and develop arguments about these associations instead of testing them, which is the goal of pure deductive research.

Developing these logical and theoretical arguments is the goal of this chapter. While the theoretical background section aimed to justify the choice of theoretical elements of interest, the results section will justify the relationships proposed and the logic behind such associations.The approach I employ will be based on three building blocks of arguments: claims, grounds and warrants (Toulmin, 1958). First, claims represent the statements and propositions I make. Second, grounds are the reasoning supported by previous studies. Third, warrants are the assumptions linking the claims and grounds (Jaakkola, 2020).

Beyond the overall method of conceptualization, Jaakkola (2020) has also suggested that there are four common types of conceptual research: theory synthesis, theory adaptation, typology and model. As explained earlier, I adopt a model-based approach in this chapter to build a comprehensive framework that propose relationships between concepts found in the strategic management, corporate sustainability and digital transformation literatures, highlighting a certain sequence in the theoretical constructs being used. As explained by Cornelissen (2017), model-based theoretical research identifies connections between concepts, introduce new ones or explains why elements of a process can lead to a certain result. In other words, the expected contribution of a model paper is to provide a roadmap for understading a certain entity or phenomenon (MacInnis, 2011), which is the purpose of this chapter. Finally, papers that employ this model approach summarize their arguments in a framework that depicts the different concepts and relationships. The results section that follow is built upon such methodology.

3.3.2 Data collection

Qualitative data collected through interviews will be used to illustrate the theoretical development and facilitate its understanding.

The selection of companies and informants was based on the type of company and on accessibility. The objective is to theorize the integration of such major transformation programs within large international incumbent firms or, as called in the literature, multinational enterprises (MNEs – e.g. George & Schillebeeckx, 2022). SME's context do not fall within the scope of this study. The goal is to address large corporations in order to understand and propose organizational, operational and communicational changes that range from cultural elements to organizational adaptations to combine digital transformation with sustainability. The underlying assumption is that studying such transformations in incumbent firms enables one to grasp a broader spectrum of potential changes with a higher level of granularity than in smaller firms, as there is a legacy in place in these larger companies.

In total, 13 different firms are represented and provide early insights on the phenomenon. These data help illustrate the theoretical concepts considered and the relationships proposed. Table 22 below depicts the region, sector and size of the firms involved, as well as the role of the interviewed person(s) within the company. Different sectors, firm sizes and informant positions are represented in order to assess from different perspectives the issues arising from the interlinkage between digital and sustainability, and to try to identify potential recurring patterns across these points of view. In terms of position, the objective was to interview executives operating at or just below the C-level, who have high-level expertise in corporate strategizing, in order to understand the perspective of informants in charge of initiating or managing those transformations. To fully leverage the richness of the stories and data collected, both the company and informant identities were anonymized and, as explained below, interviews were not recorded.

Table 22. Description of the cases

Cases	Headquarters	Sector	Employees	Revenue (mio)	Informant/s position	Informant/s location	Sustainability reporting format (2022)
Company 1	EU	Technical and safety services	10,000-15,000	1,000-2,000 EUR	Digitalization and Innovation Director	Germany	Distinct "CSR report"
Company 2	EU	Imaging and information technology	10,000-15,000	2,000-3,000 EUR	Chief Executive Officer	Belgium	Integrated report
Company 3	EU	Telecommunications	10,000-15,000	5,000-6,000 EUR	Director Logistics and Operations	Belgium	Integrated report
Company 4	EU	Chemical and pharmaceuticals	20,000-30,000	8,000-9,000 EUR	Director of Sustainability & Digital Technology	Belgium	Integrated report
Company 5	EU	Information technology	100,000-200,000	10,000-15,000 EUR	Internet of Things Practice Head	Spain	Integrated report
Company 6	EU	Conglomerate - Industrial manufacturing	300,000-400,000	70,000-80,000 EUR	Chief Executive Officer (Belgium-Luxembourg) / Head of Communications & Sustainability (Belgium-Luxembourg)	Belgium	Distinct "sustainability report"
Company 7	US	Personal care	40,000-50,000	15,000-20,000 USD	Vice President Research & Engineering / Chief Scientist and Technical Vice President	US	Distinct "sustainability report"
Company 8	US	Cloud computing, enterprise software and consulting	70,000-80,000	30,000-40,000 USD	Vice President for Strategic Research	US	Distinct "impact report"
Company 9	US	Conglomerate - Safety, healthcare and consumer goods	90,000-100,000	30,000-40,000 USD	Senior Vice President and Chief Sustainability Officer	US	Distinct "impact report"
Company 10	US	Agricultural machinery	80,000-90,000	50,000-60,000 USD	Director for Enterprise Engineering	US	Distinct "sustainability report"
Company 11	US	Consumer goods	100,000-200,000	80,000-90,000 USD	Senior Director Research Fellow	Belgium	Distinct "citizenship report"
Company 12	US	Retail	400,000-500,000	100,000-150,000 USD	Vice President / Director of Responsible Sourcing / Vice President of Responsible Sourcing	US	Distinct "ESG report"
Company 13	US	Information technology	100,000-200,000	150,000-200,000 USD	Western Europe Manufacturing Lead	Belgium	Distinct "sustainability report"

Interview data regarding these 13 cases were collected through semi-structured interviews in firms located in the US and the EU. This format enabled the inclusion of existing theories and propositions in the discussions while, at the same time, letting interviewees develop their own narratives. In other words, it enables the structuring of data collection considering theoretical propositions while remaining open to potential new theories. As explained, the goal is neither to test a specific theory nor to build new theories from these data, but rather illustrate the theory built with concrete insights from the field.

These interviews were conducted online from January 2022 to June 2022. The average length was 1 hour, and interviewees were asked the same questions following a pre-built script available in Table 23 in the appendix. The interviews were not recorded, and data are analyzed based on detailed notes taken during the interview. This should clearly be mentioned as a limitation as it can introduce biases from the researcher taking notes who could only write down what was found relevant. However, notes were taken throughout the whole interview without assessing the relevance of the narratives, and all interviews were conducted by two individuals. While I was taking notes, the other person raised the questions listed in the interview script.

In addition to the interviews, I presented the ongoing theoretical developments during follow-up meetings with interviewees. Two specific meetings were organized, to which all interviewees were invited. The first one took place on the 3rd of November 2022. All interviewees were invited for a presentation and discussion on the preliminary results. Out of the 15 persons interviewed, 4 participated in this roundtable. A second meeting took place on the 30th of November and gathered 3 innovation leaders from incumbent firms who did not participate in the interviews. Again, theoretical developments were presented and enabled to offer triangulation to the study and complete the perspectives already included in this research.

3.3.3 Data analysis

Interpretation of interview data is based on thematic analysis (Thompson, 2022) and a standard coding process. It follows the steps summarized below and is inspired by Thompson (2022). The detailed results from these analyses are available in Table 24 to Table 28 in the appendix.

1. Transcribing

Transcription took place during the data collection phase explained in the previous section. Notes were indeed taken during the interviews, enabling further refinement, if necessary, of the collection methods or scripts by detecting areas in need of clarification. Narratives of interviewees were summarized during the interview to keep only the main ideas developed by the participants. Some specific quotes have been transcribed literally during the data collection phase. Transcriptions were read right after the interviews in order to clean and structure notes, as well as extract meaning and understanding from the narratives.

2. Coding

A code is "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2013). The cyclical nature of coding as described in Thompson (2022) was used. As the dataset was manageable, I used both MS Notes and MS Excel to perform the coding process and to translate raw interview notes into structured tables of codes. In this research specifically, two rounds of coding have been conducted in a cyclical manner.

First, segments of texts have been translated into codes to extract the main idea or concept. It is the first step of making links between raw data and cognitive interpretation of it (Thompson, 2022). In the second round, I looked specifically for recurrences in the codes. Put differently, I looked to see if codes already identified could be found in narratives of the other cases studied. As indicated by

Saldaña (2013), this second round of coding is more selective. It consolidates codes that can be included under the same heading and codes that can be removed because they do not repeat. This second round was also the opportunity to rename some of the codes that overlapped with others. In summary, these two rounds facilitated the extraction of meaning and understanding from interview notes in a structured manner, as well as highlighting recurrence in the narratives. The next step aimed at grouping these codes into meaningful themes.

3. Grouping codes into themes and categories

As explained by Thompson (2022), themes are separate from codes in abductive thematic analysis. While codes are specific and concise, themes are complex and can be composed by a multitude of codes to explain a phenomenon theoretically (Saldaña, 2013). To develop the themes, I looked at the relationships between codes and how these could collectively offer an explanation of the story behind the data. In other words, these themes go beyond the data and start considering theory to explain the findings conceptually. The themes are then grouped into three main aggregate categories, mapped on the overall model. This coding exercise will illustrate the different concepts and relationships proposed, thereby supporting the understanding of the overall model.

3.4 Results

In this section, I discuss the main theoretical propositions of this study. The constructs of interest, relationships and overall process proposed are summarized by the strategic framework available at the end of this section (Figure 30. Digital transformation and corporate sustainability : integrative strategic management frameworkFigure 30).

3.4.1 Drivers

Regarding the drivers of corporate sustainability first, the literature (Rondinelli & Vastag, 1996) shows that the willingness to engage in sustainability transformations and strategies can come from elements such as the competitive environment (Ganescu, 2012), the compliance to specific regulations (van Bommel, 2011) or reputational pressure (Falkenberg & Brunsæl, 2011; Forcadell et al., 2020). One interviewee has, for example, speculated that a company that does not invest in sustainability today will no longer exist in a few years from now, due to reputational aspects. This clearly sheds light on the magnitude of reputational threats or risks for companies today.

3.4.2 Three strategic phases

I propose three steps to manage the digital and sustainability transformation, inspired by the classifications by González-Benito & González-Benito (2005) of environmental practices (i.e. organizational, operational, communicational) and the three phases of strategic management (David, 2011; Engert et al., 2016; Rêgo et al., 2022): formulation (including organizational adjustments), implementation (under the form of potential actions or projects) and evaluation (including feedback to internal and external environments). Figure 27 below describes the drivers of corporate sustainability and the three strategic phases for integrating digital transformation with it.

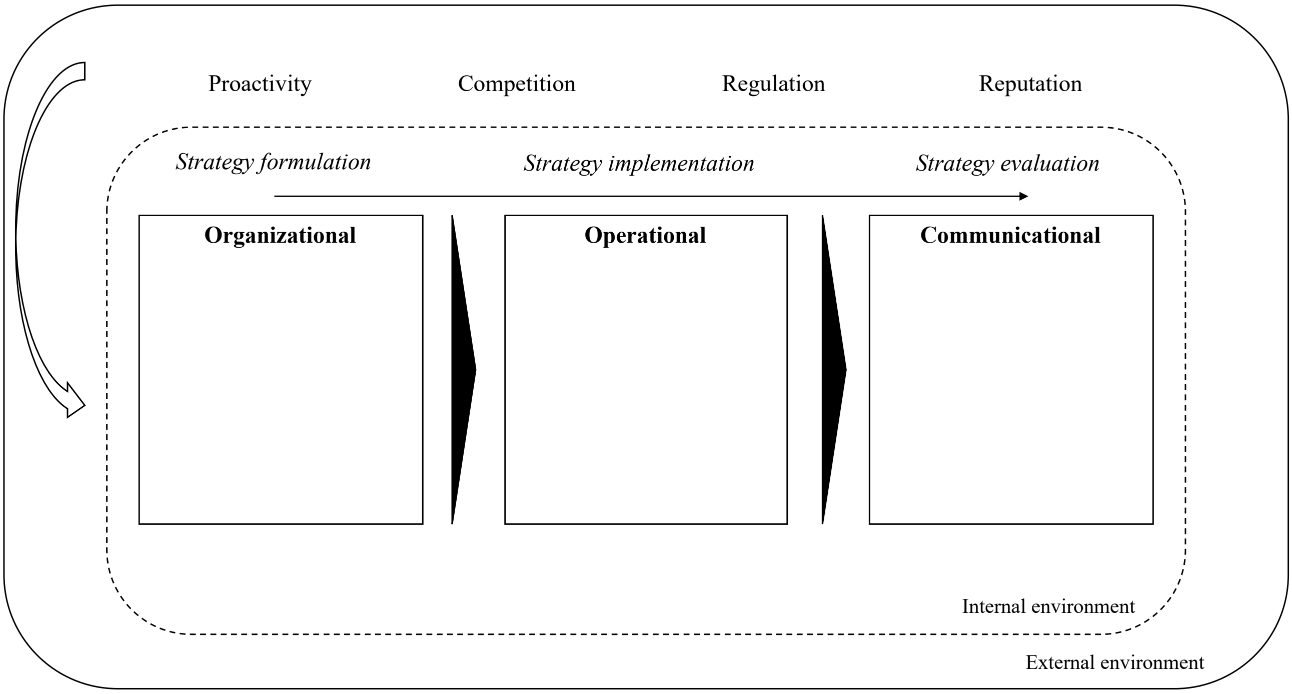


Figure 27. Integrating digital transformation with corporate sustainability: three strategic phases

3.4.2.1 Strategy formulation: organizational phase

The first step of strategy formulation is organizational and is composed by three sub-steps, as depicted by Figure 28. First of all, the company needs to envision the change at the highest level, meaning at the C-suite level. Interviews have for example emphasized the importance of the chief executive officer in that matter and the fact that a top-down steering is needed to drive the company towards sustainability objectives. They emphasized the need for a central lead with a team of functional pilots. This potential change requires harmonization as well as investments from the business, especially in the case of business-unit centric organizations.

The company must set a clear direction towards sustainability and leverage digital technologies to support this sustainability agenda through redefining its purpose, vision and mission (George et al., 2022) and developing strategic plans. According to Millar et al. (2012): ‘implementation and organizational change are the key issues the sustainability agenda is demanding action on. This requires a change of thinking, a change of attitude that usually needs to start with leadership.' The literature has clearly shown that in order to be effective, corporate sustainability should become an integrated part of business strategy (Engert et al., 2016), meaning that it should be part of the vision and the culture, governance and performance systems (Steyn & Niemann, 2014), as well as part of everyone's work (White, 2009). To illustrate this, interviewed firms have emphasized the need for clear objectives and targets that are long-term oriented and that go beyond financial metrics as part of the strategic plan. As mentioned by some of them, there is a need to move beyond year-on-year Profit & Loss (P&L) accounts at the board level and define appropriate incentive schemes at all levels of the organization.

The second organizational component concerns the culture. This step requires the company to focus on human beings and engage with people, as well as establish a culture based on transparency and collaboration. It particularly links to human beings' characteristics and their willingness to change, which we can relate to Lewin's (1947) 3-Step model of change. Some interviewees stated that there is no obstacle except the mindset and will of people to change. According to some of the companies represented in the sample, causes of inertia vary across organizations and countries, and can relate to topics such as habits, preferences, cultures, legacy and/or implicit structural incentives. Interviewees reported that it is crucial to keep the dialogue open to build a clear understanding of what makes people willing to change and figure out how to make them work together towards a more sustainable future for the company, customers, stakeholders, and the planet.

Coming back to Lewin's (1947) 3-Step model of change, there is a need first to "unfreeze" (e.g. Fisher (2022), based on early propositions from Lewin (1947) on the three aspects of change: unfreeze, change, refreeze). To do so, firms should clearly understand people and what prevents them from changing in order to build the right mindset to require firms to facilitate learning (J. H. Grant, 2007) and therefore enable individuals to understand and restructure their perceptions of the world around them (e.g. Burnes (2004) based on Lewin's propositions). Perceptions, feelings and actions are strongly related to the group an individual belongs to (Allport, 1948). Related to this aspect specifically, interviews have shown that firms are trying to build small networks of change within the organization by identifying so-called "*champions*" who can change perceptions and incite people to change. Companies also state relying on such *champions* for mentoring and coaching purposes.

This second step related to the culture concerns people within but also outside firms' boundaries. Sustainability and digital transformations, particularly through the data facet, require the alignment of a series of stakeholders and collaboration with external ecosystems. In 2004, Burnes argued that "to survive, organizations need to reconfigure themselves to build internal and external synergies, and managers needed to encourage a spirit of innovation, experimentation and entrepreneurship through the creation of strong, appropriate organizational cultures" (Collins, 1998; Kanter, 1983; Peters & Waterman, 1982; Wilson, 1992). More recently, external partnerships and participation to business ecosystems have raised the attention of both strategy research and practice (Jacobides et al., 2018). Related work on alliance portfolios offers further insights, and papers such as Uzzi's (1997) have shown that firms effectively balance cooperation and competition, based on a portfolio approach made of cooperative and competitive alliances (Hoffmann, 2007). In practice, interviewees declared adopting portfolio strategies composed of a mix of cooperation and competition, clearly assessing whether certain products or activities should be made, bought, or co-created. In order to function, firms emphasized the need, especially for sustainability issues, to work with certifications and common KPIs, and stated that they tend to work with frameworks specific to external partners.

The third organizational step concerns the resources that should be available to implement such strategy and related transformation, and that requires investments. Some companies today declare having clear targets regarding their suppliers. For example, one company stated that they have a commitment that 80% of their investments will be spent on suppliers that apply science-based targets. In regard to these investments, it is crucial to keep in mind that investments have a life cycle and that the legacy of firms must be taken into account. As indicated by one interviewee, the life cycle can extend up to 40 years in some industries that rely on heavy equipment, and it may take time to replace this legacy.

Next to suppliers, these investments can concern the acquisition of human or technical resources. Human resources relate to skills and work methods that include eco-design, end-to-end thinking and agility. Several interviewees emphasized the notion of lean and agile management, characterized by fast iterations, is crucial for maintaining resilience and competitiveness in crises, indicating the ability to quickly adapt to market needs. Another firm also emphasized the importance of experimentation, specifically that the company openly allows employees to make mistakes. They prefer that people learn from mistakes than not take any initiative. In their own terms, their approach is to "*start fast and potentially fail fast*," which they do consider as learning opportunities. To acquire these specific skills and methods, companies can rely on two complementary approaches: learning and hiring. They have the option to offer the needed training programs to employees while, or to hire people capable of changing the perspectives of the existing teams to which they are introduced.

Technical resources mostly concern the maturity of information systems regarding infrastructure and data. Companies emphasize the need for a common and reliable infrastructure, both internally and in terms of infrastructure shared with external partners. In fact, new digital infrastructure such as accounting and reporting systems can be used as enablers to facilitate participation in joint entities, such as the GLEC (Global Logistics Emissions Council).

Data, as we will see in the description of the next building block below, is crucial. This specific resource can be related to the knowledge-based view, an extension of the resource-based view that considers knowledge as the most important and strategic resource for a company (R. M. Grant, 1996). When it comes to the integration between digital technologies and corporate sustainability, technologies creating or capturing data offer knowledge that provide a better understanding of the business, where the impacts lie and what the areas of improvement are.

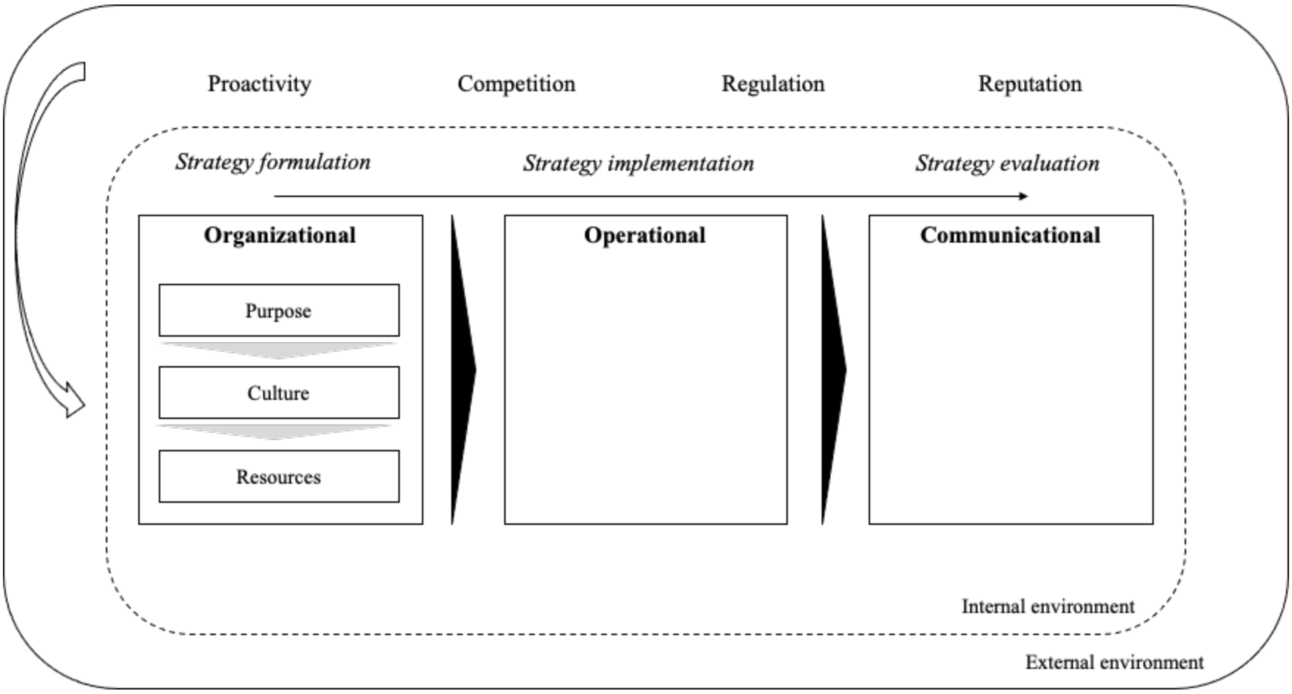


Figure 28. Integrating digital transformation with corporate sustainability: organizational phase

3.4.2.2 Strategy implementation: operational phase

The second building block of the framework relates to implementation and is operational in nature (summarized in Figure 29). It focuses specifically on areas where digital seems to offer potential or, as stated in the literature, functional affordances (Markus & Silver, 2008 the notion of affordance being initially proposed by Gibson, 1986). Markus & Silver (2008) defined affordances as "possibilities for goal-oriented action afforded to specified user groups by technical objects."

This second step is also what I call strategy implementation, specifically related to digital transformation. It emphasizes specific areas where digital may support a corporate strategy that incorporates sustainability, as described above. It is worth emphasizing that digital transformation is the focus of this chapter, but the operational component of sustainability strategy could extend beyond the application of digital technologies, as they are not the only potential solution to sustainability issues. Overall, this operational building block offers an extension to the work by Seidel et al. (2013). Digital technologies can indeed help companies quantify sustainability impacts, optimize the use of resources or organizational processes and support the reinvention of products or business models.

These three categories of use cases can also be viewed as steps, each of them intending to have a greater impact on the environment. The first step may not bring any improvement per se, but there is a need to take initial measurements to be able to track any progress regarding sustainability efforts. As explicitly mentioned by some interviewees: "*you can't improve what you don't measure*." The first step should be to look for ways to objectively quantify current and future impacts of firm activities using, respectively, data collection and predictive capacities offered by digital technologies. In other words, digital technologies can help collect and aggregate data and, in turn, the data collected can support simulation, modeling and prediction activities.

In practice, interviews have highlighted the important role played by sensors embedded in technologies such as the Internet of Things or smartphones that support the collection of enormous amounts of data related to internal operations as well as activities along the value chain, be it with suppliers or customers. Two firms mentioned that distributed ledger technologies, such as blockchain, are a way to bring transparency in complex supply chains. Through the certification mechanisms it involves, these kinds of technologies enable firms to better understand the activities along the supply chain. Indeed, according to one interviewee, these technologies bring "*more transparency in the supply chain, direct payment and more equality*." A digitized supply chain was also emphasized by another company, which stated that digital technologies enable the exchange of live data from factory metering and the monitoring of air and effluent discharge. In this regard, they allow for a better understanding of each manufacturing step. Gathering the right information can inform the supplier scorecard which, in turn, helps sourcing teams to make the best business decision when combined with an "*Impact P&L*" that measures the social and environmental impact and translates it into a cost impact for the planet. Upstream activities regarding production and supply chain management and the collection of data can also help better understanding downstream activities, such as consumption patterns. For example, a company mentioned the use of sensors or smartphones to obtain consumer feedback and better know when, how and for how long their products are worn.

Data collected and combined with high-end digital systems can support lifecycle assessments that often require sophisticated calculations. These assessments enable managers to better understand where the impact lies and what action they can take to reduce it. Most executives confirm that faster and better decisions to accelerate investments or actions are favored when data are presented in the right format. These data enable companies to feed transparent and reliable reporting, going beyond financial metrics and targeting all stakeholders, including investors. This reporting aspect will be tackled in the communication section below. Finally, data can also feed predictive activities. One company explained, for example, that they build predictive models to estimate the environmental impacts of future products in terms of CO_2 emissions.

To sum up, these propositions are in line with Seidel et al.'s (2013) findings, which suggest that "information systems afforded possibilities for cognitive activities through which individuals across the entire organization could frame, interpret and understand the multilayered and complex issues related to the environmental sustainability transformation." In other words, this relates to a sensemaking process that is, still according to Seidel et al. (2013), "an important process in the context of sustainability initiatives, as the multilayered pressures leading to the transformation require organizations to adopt a greater openness toward new information, information from multiple sources, and information that challenges current beliefs about work practices." Seidel et al. (2013) posited that information systems enable reflective disclosure that allows for reconsidering beliefs and action formation and outcome assessment, as a result of information democratization. This first step is particularly important because, as noted by George et al. (2022), "one of the most enduring insights in social science is that nothing gets done by organizations if it is not measured."

Next, digital technologies can be leveraged to improve the current situation by optimizing a series of elements like energy or organizational processes. This step is about bringing efficiency to the organization while minimizing the negative effects of business activities, thereby improving the environmental footprint. Seidel et al. (2013) calls this "output management." This second step is a current priority for interviewed firms. When we ask how digital and sustainability transformation intersect with each other, productivity potential of digital is the key focus of the executives interviewed. To illustrate this, one company raised the example of precision agriculture. Precision agriculture, which leverages digital technologies to improve seed placement by accounting for a series of variables, is expected to lead to better yield and lower resource use. Next to resource use, companies explained that digital technologies can support organizational efficiency, freeing time for more value-adding activities.

According to some sources like McPhearson (2021), the environmental transition will not be possible unless we holistically consider and rethink our systems and business models. The last use case is different in that sense, as it is not only about minimizing the negative, like in the case of optimization, but rather about adopting a more holistic and systemic approach to reinvent models at the level of products or at the level of the whole business model, notably with the development of data-based offerings or models. In practice, interviews have shown the potential role of tools such as generative design thinking and virtual prototyping. As explained, one firm stated that they are capable of estimating and predicting CO_2 profiles of future products. In addition to the way products are prototyped and designed, digital innovation and the use of certain technologies will also aid in tailoring an offering to specific customer needs. In the specific case of printing, for example, one company stated that digital printing, which replaces old printing techniques like engraving that require large amounts of metals and energy, offers a great differentiation potential due to a higher quality and more flexibility for customization with less impact.

These use cases highlight the reinvention of one aspect of the existing business model: the product. But digital technologies, particularly data, can also used to build completely new or complementary business models. One example relates to data-enhanced products and the subscription model they enable. Indeed, data can be used on top of traditional product offerings to offer novel insights on the use of products, thereby improving their lifespan. These data can be monetized on a regular basis through a subscription model.

On top of the subscription model that digitally-collected data enables, digital technologies are also believed to be an important enabler, if not accelerator, of circular models. The use of sensors enables a better understanding of patterns of consumption, but it also helps track important material information on products to support transition toward the circular economy. It can indeed ensure product and material data is communicated across the industry, enabling products to be identified for resale, reuse and recycling. All these data can be shared on a cloud platform to enable a whole network of circular partners, deriving value from products that were previously intended to be waste by reusing or recycling them.

This last category, or step, of use cases also comprises the virtualization of physical activities that Seidel et al. (2013) called delocalization. To illustrate this, firms mentioned that digital technologies accelerate their ability to decrease environmental impact by enabling the deployment of initiatives where, for example, physical transport is avoided. More specifically, one company stated that they make use of digital tools to perform activities remotely, such as inspections or audits on big infrastructure like wind turbines.

Overall, this last area of potential complements the propositions of Seidel et al. (2013) on functional affordances in the context of a sustainability transformation. Indeed, the list of affordances proposed at that time neglects the potential reinvention affordances offered by the use of digital technologies or, more generally, information systems that have been highlighted above and illustrated by concrete examples from the interviews. Although the optimization of business as usual still seems to be the focus of the few companies interviewed, reflections on model or system-based changes in terms of circularity seem to be emerging as well.

At this stage, it is also worth bringing some nuance to these positive use cases or functional affordances. First, as extensively studied in the literature, the digital sector itself has direct impacts that cannot be neglected (Freitag et al., 2021; Stuermer et al., 2017). Even though this aspect was not raised in the interviews, direct impacts of digital such as production impacts or energy use should be considered when evaluating the net contribution of digital technologies to sustainability. As firms continue implementing such use cases and measuring their impacts, we should gradually be able to better estimate the net environmental impact of digital projects and their real contribution to the overall environmental transition of our economies. In the meantime, it is crucial to remain prudent with the improvements it brings and related estimates.

Another nuance that should be emphasized here is specifically related to optimization potential. Indeed, efficiency effects of the use of technologies or innovations in the past have been accompanied by rebound effects (P. H. G. Berkhout et al., 2000) that may come from changes in behavioral patterns as the resource becomes more effective and, consequently, more attractive. In other words, we tend to consume more of these resources, negating the efficiency gains. The context of high uncertainty surrounding the net impact of digital projects should call for caution from companies regarding use of digital technologies for sustainability issues.

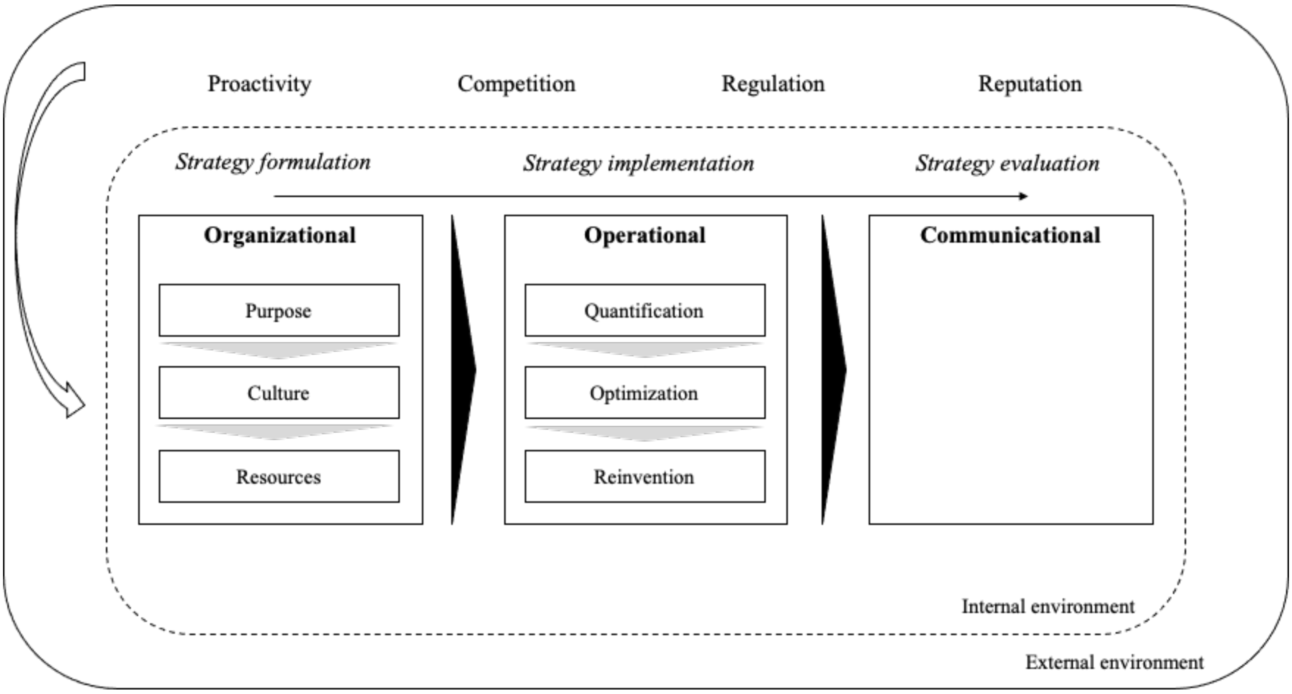


Figure 29. Integrating digital transformation with corporate sustainability: operational phase

3.4.2.3 Strategy evaluation: communicational phase

Last but not least, the communicational step relates to evaluation and reporting of these efforts, as well as communication within and outside firms' boundaries. Sustainability reporting has attracted researchers' attention since the first publication of environmental reports in the early 1990s (Kolk, 2004). Different elements are worth mentioning in regard to the communicational pillar of the transformations investigated in this chapter.

First, the reporting and communication actions should be based on audited results. Firms declared, for example, that they rely on external auditors to perform such assessment and validation, or that they rely on established framework or standards. Among others, the following frameworks have been cited during the interviews: Science-Based Target initiative (SBTi), Sustainability Accounting Standards Board's (SASB) Software, the IT Services sector guide, the Task Force on Climate-Related Financial Disclosures (TCFD), Global Reporting Initiative Standards (GRI), the Ten Principles of the UN Global Compact (UNGC), and the World Economic Forum — International Business Council's Stakeholder Capitalism Metrics (SCM). A recent study (Asante-Appiah & Lambert, 2022) showed that the involvement of auditors during ESG risks periods are associated with both improved future ESG-related reputation as well as firm outcomes. When it comes to digital issues, firms tend to rely on measures defined internally that are not always part of the reporting. Still, firms declared being interested in standardized frameworks for the digital facet of their transformation, but stated that this does not exist yet. With the awareness of environmental and social issues related to the use of digital, particularly in the current context of democratization of generative AI tools, the interest for and relevance of such digital framework may be expected to rise in the near future. Some initiatives are already taking place under the form of charters, such as the Sustainable IT charter inviting organizations from all sectors to comply with a series of ESG criteria. This could serve as inspiration for standardized frameworks for the digital component of firms' current transformations.

Second, reporting makes it possible to share progress. Looking at the sample of interviewed firms, it is worth noting that all firms interviewed report their sustainability – or environmental, social and governance (ESG) impacts, through either distinct or integrated reports. However, a key issue today is that there is a proliferation of environmental standards (e.g. Rondinelli & Vastag, 1996 and still confirmed in the press notably by The Economist in 2020) and firms do not assess and report environmental impacts based on the same indicators (see Singh et al. (2012) for a review of sustainability assessment methodologies). The Economist argued in 2020 that more than 360 ESG accounting standards exist, and the world needs convergence in that regard. Despite this situation, firms report their sustainability impacts in various forms, like using the Materiality Assessment or by relying on defined standards such as those proposed by the GRI (Global Reporting Initiative) or SBTi (Science-Based Target initiative). Looking more closely at sustainability reports published by the interviewed firms (see Table 22), it can be observed that firms whose headquarters are in the US all report their impacts under distinct reports and different names such as "sustainability report," "ESG report," "CSR report," "impact report" or "citizenship report." Conversely in Europe, most firms report sustainability impacts under integrated reports, thereby integrating it with more traditional annual and financial reports. While it is not the purpose of the current study, this could shed light on different considerations of sustainability within the context of multinational enterprises worth investigating in future research.

Regarding the current need for convergence, The International Sustainability Standards Board (ISSB) issued on June 2023 its sustainability-related standards, IFRS S1 and IFRS S2, creating a common language regarding climate-related disclosure efforts. Regarding the role of digital technologies in this communicational step, studies have recently shown the positive effect of digital technologies and innovation (Pizzi et al., 2023), notably in terms of the accuracy of the evaluations.

Finally, communicating these results beyond reporting is relevant both within and outside firm boundaries. Within firm boundaries, this last step is allows feedback loops to take place and encourages the continuous realignment of the strategy with the results to keep improving the situation. This observation supports the importance of organizational learning (Levitt & March, 1988). Strategy is not a one-shot exercise and should be updated based on the latest results available, as it is crucial for firms to keep positive feedback loops ongoing. As explained by some interviewees, this enables the firm to understand the relevance of changes implemented and it enables executives to build buy-in among shareholders regarding the vision set. Within academia, there is anecdotal evidence that investors value ESG because they consider that ESG risks and opportunities can impact organizations' long-term performance and valuation (Cohen et al., 2011; Krueger et al., 2020). The analytical theory in particular argues that investors value environmental initiatives and socially responsible activities (Klassen & McLaughlin, 1996). Although being addressed by only a few authors, internal communication with regard to sustainability enable also employees to understand and trust a sustainability statement (Engert et al., 2016). The literature also shows that the usage of internal communication channels such as intranet, emails or seminars are essential for the implementation of sustainability strategies (Siebenhüner & Arnold, 2007). The internal use of KPIs and incentives could enable further alignment of the corporate strategy's integration of sustainability. As an example, some interviewed firms indicated using stock option packages that would reflect the global ESG results of the company. These incentive schemes are included in the tools designed to ensure feedback loops with the organizations, enabling them to assess the results of the initiated transformation.

On the external side, feedback loops enable the company to raise general awareness of sustainability and digital issues, which are increasing in prevalence, while also influencing other actors to take part in such transformation journeys and keep aligning the ecosystems. As explained, reputational risks related to these issues may put some pressure on companies today, and therefore it seems important for firms today to control their reputation. This can be done by reporting and communicating not only on the efforts, but on the actual results of these efforts. Finally, it is also worth noting that the reputational fears could clearly be observed especially during one of the interviews. One interviewee, CEO of the subsidiary of a large multinational company, was accompanied by the communication director. This clearly highlights fears from reputational risks, as mentioned in the beginning of this section, and therefore explains the willingness to control the overall communication on such issues.

Figure 30 below includes this last communicational phase, thereby comprehensively summarizing the strategic framework developed.

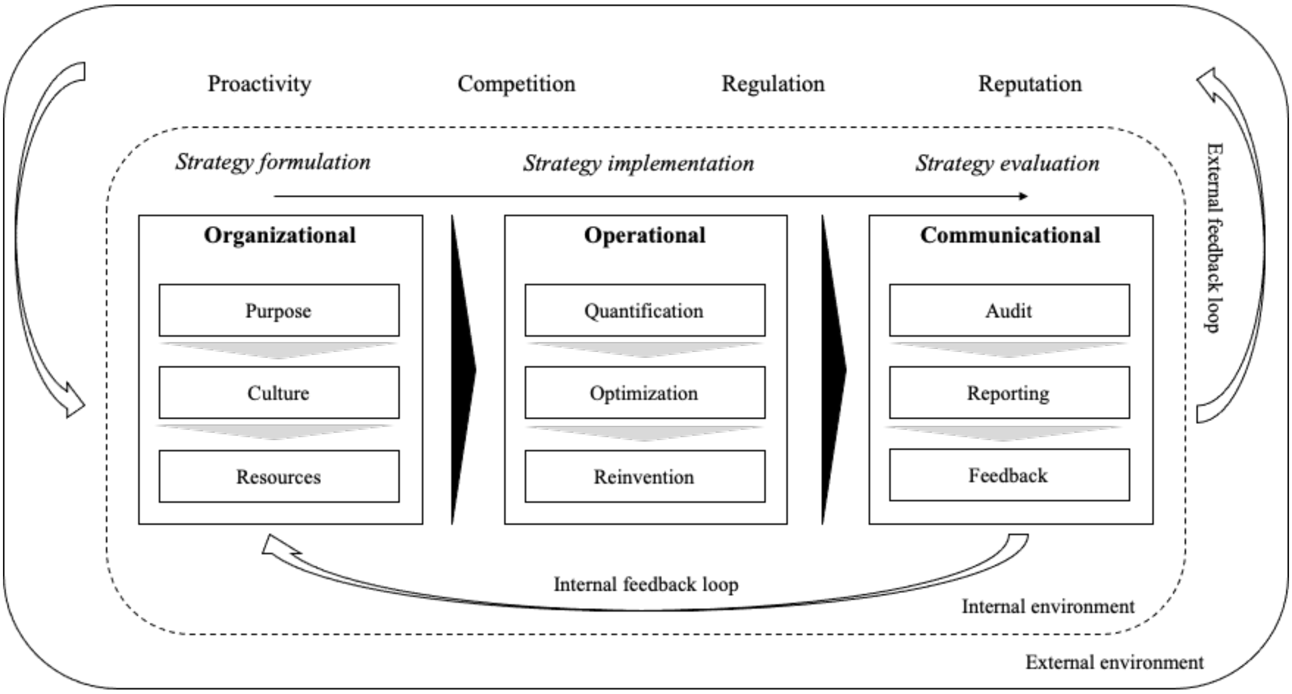


Figure 30. Digital transformation and corporate sustainability : integrative strategic management framework

Source: author's own development

3.5 Conclusion

Adopting a model-based and conceptualization approach, this chapter proposes a guiding strategic management framework for multinational enterprises to integrate digital transformation with corporate sustainability and strategy.

By doing so, this chapter brings contributions to both theory and practice. In terms of theory, it proposes a comprehensive strategic management framework to leverage potential synergies between digital and environmental transformations of firms. This framework is composed by theoretical concepts that go beyond the analysis and description of specific digital use cases that have been documented in the literature (Diaz & Montalvo, 2022; Hanelt et al., 2017; Junge, 2019). Concretely, it suggests joint drivers of such transformations, such as competition, regulation or reputation. It also emphasizes the central need for the redefinition of firms' purposes, cultures, and channels through which synergies between digital transformation and corporate sustainability strategy can be exploited. It suggests also that corporate sustainability should be the higher-level strategy to be followed, while digital transformation is only one of the potential means to support this strategy. There is therefore a clear hierarchy between the two topics that concepts such as the *twin transition* do not reflect. It sounds as if both objectives, digital transformation and sustainability, are on the same level. While we can make hypotheses regarding the rationale of this perspective at the political level, notably in terms of digital sovereignty, this does not mean that economic actors should strategically treat both as equal in nature. Finally, based on this research, I propose a review of Gong & Ribiere's (2021) definition of digital transformation that is better integrated with corporate sustainability:

"Digital transformation is a fundamental change process enabled by digital technologies ***at the service of a strategic and sustainable purpose***. Concretely, it aims to bring ***potentially*** radical improvement and innovation to an entity [e.g., an organization, a business network, an industry, or society] to create ***sustainable*** value for its stakeholders by strategically leveraging key resources, capabilities, ***and partnerships***."

In terms of practice, this steps-based framework has been developed in such a way that it is easily accessible and applicable by business leaders. This chapter offers practical guidance to integrate digital transformation with corporate sustainability, providing concrete and illustrative insights on the way companies currently deal with digital and sustainability issues. Still in terms of practice, these results can be valuable to policymakers as they identify early synergies and provide a sense of the current maturity of the topic within large incumbent firms. As research between both topics evolves, this may guide policymakers in fostering the development of digital technologies that have a proven impact on the environmental strategy, while minimizing the development of counterproductive innovations and offering the right business environment for such intertwined transformations and strategies to be conducted.

Next to its direct contribution to the academic literature and to practice, this research opens doors for future research at the intersection between digital and sustainability in the context of large private organizations. Indeed, the building blocks of this framework can be tackled and further refined separately. While the goal of this chapter is to provide a general overview and guide for the combination of digital transformation with sustainability strategy, it is crucial to further investigate each component as firms go along with these transformations. This framework has been built based on current theories and conceptualization efforts but will need to be updated as firms learn along the way, with new digital technologies emerging and new data becoming available to test the theoretical propositions included in the model.

Furthermore, this framework can be complemented with the direct impacts of digital technologies to ensure that the full picture is considered by firms when assessing the impacts of digital technologies on the environment. Indeed, this research mostly highlights the ways firms can leverage digital for sustainability agendas. However, digital technologies also have direct (e.g. production, energy use, etc.) and indirect (e.g. obsolescence, etc.) environmental impacts, as well as social considerations that should be incorporated in the reflection that are hard, if not impossible, to estimate at this stage. The observations from this research have shown that these impacts are not the top priority of industry leaders to date, but research needs to evolve towards a holistic consideration of such intertwined transformations.

3.6 Appendix

Appendix A : Interview

Table 23. Appendix A.1 : Interview script

1. Tell me about yourself, your role, and the mission and vision and strategy – product leadership, customer intimacy, or operational excellence - of your company.
2. How would you describe the culture of the company through the lens of digital transformation and social impact innovation? Is the culture an enabler or an impediment to the implementation of either?
3. Where is your organization on a scale of 1 to 10 in terms of the digital transformation of your offerings in your top 3 markets? A 10 would represent that fact that your organization already generates the majority of its revenue from digital subscription services. Where would you like to be in 2025?
4. Which key strategic initiatives that, while improving the current business, have the most room for improvement from the "Green Digital" perspective (i.e. digital acceleration)? Consider the chosen strategic discipline (Product Leadership, Operational Excellence, Customer Intimacy), which investments should be made to most profitably accelerate innovative growth initiatives related to your key offerings that accelerate environmental and social change?
5. Where is your organization on a scale of 1 to 10 in terms of digital transformation regarding your sustainability goals? A 10 would represent an increase in likelihood of meeting your long-term sustainability goals by 50% due to digital tools/insights/efficiency gains that provide the needed insights to accelerate progress.
6. What are the economic engines for the organization and how are they being leveraged currently to grow the business? How do they align with the key strategic digital accelerators outlined above? How does the business leverage strengths of the economic engine to accelerate the transition to a Green Digital organization?
7. What are the barriers that inhibit the pursuit of these strategic digital initiatives? What are the costs to overcome them?
8. Describe some corrected missteps that the organization has made during this journey? What have some of the pitfalls been?
9. Which external partnerships are needed to create solutions used to surmount these barriers and accelerate the Green Digital transformation? What is needed to organize, execute and maintain an external ecosystem that will continually bring ISII into the customer offering?
10. How is the company leveraging product design in your top three markets to ensure that digital thinking is embedded in each new innovation related to your offerings? How is the company wrapping a digital component around legacy and emerging offerings? How are these offerings aligned with the corporate strategy?
11. How is the metaverse impacting your business? What are your plans to collaborate or conduct business in the metaverse?
12. How do you validate your progress towards this ISII/digital transformation? What is the internal/external mechanism?
13. Would you like to be a part of the final roundtable where results are reviewed?

Appendix B : Empirical findings

Tables below illustrate the results from the interviews and coding approach.

Organizational level

Purpose

Table 24. Appendix B.1 : Coding results - Purpose - Organizational phase

Text segments	Codes	Theme
• *Importance that top management, especially CEO, supports this. It must be in the highest-level strategy.* • *Top-down beginning without much resistance from the company. Importance of the board.* • *There is often a pull from senior leaders these days to ensure that they are aligned with the direction of sustainability.*	CEO initiative	Purpose
• *What's the next 50 years? Creating a smart and sustainable enterprise – embedding intelligence into all of our products and making those products sustainable. Purpose-led and performance-driven.* • *Clear that sustainability is high on the agenda - every investment is focused on the green purpose.* • *technology with a purpose - the whole activity needs to serve overall objectives e.g. efficiency, sustainability.*	Vision, mission and purpose	
• *Strategic plan launched beginning of 2020 gave it a strategic orientation and accelerated the movement.* • *They also implemented a strategy related to ESG/Sustainable development that is accompanied with specific short, mid and long-term objectives. Efforts are made in this area and Digitalization is part of the portfolio and managerial transformation topics.*	Strategic plan	

Culture

Table 25. Appendix B.2 : Coding results - Culture theme - Organizational phase

Text segments	Codes	Theme
• *Mindset is the biggest issue. How to change this corporate mindset? leaders must have the vision and must also see the danger and threat in the crisis around us.* • *No obstacles: it's in people's head. It's a question of mentality and willingness.*	Mindset	Culture
• *Organization was very GBU centric but now it becomes more centralized so there is a need for harmonization and investment from the business itself.* • *Central lead (for sustainability issues) with team of functional pilots.* • *Centralized digital service team - try to keep the company on the same platform (e.g. SAP).*	Centralization	
• *Culture is neither an enabler nor an impediment. Can do culture with customer vision.* • *Focus on collaboration and combining goals to deliver the maximum value for the client.* • *One of the strategic forces is customer centricity/business centricity - good interface with clients including ways to share production data.*	Customer vision	

• *Transparency is key. One of the 3 pillars is transparency regarding product usage.* • *Culture is transparency and collaboration.* • *Investments and transparency are crucial.*	Transparency	
• *Keeps the organization flat and collaborative. Treat employees like customers who pay for their benefits and salaries with the best years of their lives. Team intimacy is a culture that emerges.* • *More collaboration, businesses will be less siloed.* • *Culture is transparency and collaboration.*	Collaboration	
• *Reverse mentoring - younger coaching "dinosaurs"* • *To overcome the barriers is to use network effects - work with people that are enthusiastic and build champions around the topic and build communities around that and spread the message and work on that goal.*	Mentoring	
• *Think in terms of ecosystems, collaborating with competitors (coopetition).* • *Industry needs to identify where collaboration is best: for example, packaging - you have to work together. It is important to create boundaries between common challenges and areas where you want to compete.* • *Prefers to do things on their own. However, much of the climate change work is showing that collaboration is needed.* • *Good external partnerships to evolve together : relevant shared AI models*	Ecosystem approach	

Resources

Table 26. Appendix B.3 : Coding results - Resources theme - Organizational phase

Text segments	Codes	Theme
• *Every investment is focused on the green purpose at the end.* • *There is a commitment that 80% of our spend will be spent on suppliers with science-based targets.* • *Important to keep in mind that investments have a lifecycle, for some equipment at industrial clients it's +- 40 years. We must take the time to replace the legacy into account.*	Investments	Resources
• *Transitions are fast but competences/skills of people are a source of difficulty. To overcome it, two solutions: training/learning and renew part of the teams - introduce in the teams people that will change perspectives. They need to look for competences externally.* • *Upgrade and upskill: huge program on upskilling (AI, management of data, etc.).*	Skills	
• *Incentives schemes depending on the building blocks of the strategy - CEO included.* • *Sustainability incentives for everybody, depending on the group's results - 10 to 20% related to sustainability.* • *Long term: stock options based on performance on ESG worldwide.*	Incentives	
• *Circularity is embedded in all business units - circular design for products, selection of partners (in RFP, 20% of criteria concern circularity/sustainability).* • *New ways of building products focusing on circularity - smart cars, buildings, home: ask how each piece of it can be reused and recycled.*	Eco and circular design	
• *Change management is their normal way of doing business - so resilient in crises, lean and agile.* • *Factories must be sustainable AND agile to what the market needs.* • *We must become more agile and reduce time to market – iterate and innovate faster to remain competitive.*	Agility	
• *Work with Gartner etc. looking at market trends and at what clients' demand are. Have this tech radar that shows what is coming.* • *Learn a few methods (design thinking) to approach things and manage change.* • *Need standards: important to have aligned methodologies in different industry associations.*	Methods and benchmarking	

• *Digital is clearly an acceleration factor. But there are barriers such as data structure: important to work on the data to accelerate sustainability.* • *Correlation between digital maturity - sustainability maturity: 'measuring is knowing.' Without digital, difficult to do real time, predictive, autonomous etc. for sustainability.*	Information systems	

Operational level

Table 27. Appendix B.4 : Coding results - Operational phase

Text segments	Codes	Themes
• *Digital enables the democratization of data - giving the tools to aggregate data.* • *Digital allows to capture data and help in faster decision making.* • *Digitize how we complete our research ideally obtain instantaneous consumer feedback in everything we do e.g. when do people wear our products, how long do they wear them, etc.*	Data collection and aggregation	Quantification
• *Accelerate the development/deployment of simulation tools & digital feedback loops.* • *Predictive capacity to help develop new products and their CO2 profiles.* • *Lifecycle analysis: require sophisticated calculation with high end systems.*	Simulation, modeling and predict	
• *Digital support productivity: using less resources (energy) to do something, thereby reducing CO2.* • *Digital helps whenever it comes to managing resources in a more effective way - Resources optimization. This will be the case for a certain period of time - much room for improvement.*	Energy efficiency	Optimization
• *Everything that can make the processes more efficient.* • *Digitize how we go to market – do more sell and learn raid testing rather than a huge study. Instead – what is a consumer willing to pay instead of putting it on the market – digitizing selling and learning for rapid iterations.*	Organizational efficiency	
• *Generative design thinking. Virtual product prototyping has increased 10-fold due to COVID – using digital prototyping out of necessity.* • *Digital printing - market share is low (<3%) but they are required to develop it because there are needs for customization, flexibility and footprint challenges.*	Product innovation	Reinvention
• *Another model – a subscription model has not yet been successfully executed. Data is being collected to help the farmer continuously improve their yield and sustainable outcomes. This data is not yet being leveraged but is being collected so that this data can be organized and sold for customer value eventually. The tractors are our data gatherers as well as our current delivery model for Precision Agriculture.*	Business model innovation	
• *Green digital is about supporting initiatives where digital enable to avoid physical transport.* • *COVID19 crisis allowed to perform remote audit and remote inspections, which teams were developing before Covid. Covid was an opportunity to scale easily.*	Virtualization	

Communicational level

Table 28. Appendix B.5 : Coding results - Communicational phase

Text segments	Codes	Themes
• *Numbers are validated by external auditors to avoid green washing* • *External mechanisms, benchmark (notation agencies) + extra financial publications. Everything is structured and coded and there are data shared on the progress*	Validation	Audit
• *Innovation is measured - balanced scorecard + KPIs checked from strategic level (executive level).* • *Sustainability: external audits - as part of the roadmap, trying to define KPIs for the different areas.* • *Sustainable development: progress is tracked, update each trimester.*	KPIs	
• *The contents of the sustainability report are informed by regular ESG materiality assessments, which identify key topics that are most important to our stakeholders and to our success as a business. This report is also informed by leading ESG disclosure frameworks and standards, including the Sustainability Accounting Standards Board's (SASB) Software and IT Services sector guide, the Task Force on Climate-Related Financial Disclosures (TCFD), Global Reporting Initiative Standards (GRI), the Ten Principles of the UN Global Compact (UNGC), and the World Economic Forum — International Business Council's Stakeholder Capitalism Metrics (SCM).* • *Some chemical goals are monitored through quality team or through testing. Factory efficiency goals are validated through 3rd party consultants who would go into the factory and validate results. Third parties are used to validate progress to the overall sustainability goals which are reported to the shareholders.*	Report	Reporting
• *Ambitions go beyond legislation: circular company by 2030, net zero by 2040 + raise awareness of clients on Green/Environmental challenges.*	Awareness	Feedback
• *A company that does not invest in green today will not exist anymore in 10 to 20 years. Will it bring growth? It's linked to reputation. It becomes important for customers - differences between age categories but it does become important. Societal aspect, reputation go hand in hand with growth*	Reputation	

PART III: CONCLUSION

1 Reflecting on this thesis

1.1 Summary of the findings

Adopting a research-forward approach, the main aim of this thesis is to bring relevant insights from the field to inspire both theory and practice. The main driver of this study is to bring impactful theories back to the field on current real-world problems and challenges being digital transformation and sustainability. It aims to move away from common, simplistic narratives that usually oppose paradigms and the models they are based on, when these could be combined (e.g. *green growth* based on decoupling versus *post-growth* based on sobriety or sufficiency).

It also made me question the dominant narratives underlying our techno-economic paradigm relying on digital technologies. Who would indeed refuse a digital *solution?* Who would not trust a *smart or intelligent* machine? Who would question the impact of the *cloud?* Who would not rush into data, considered as *the new oil?* Yet, these topics require precaution and nuance. No, digital is not always the solution. No, digital is not smarter than us, humans, if we consider intelligence in all its complexity. And yes, despite its virtual connotation, the cloud is material (Monserrate, 2022). Finally, data is not the new oil, but rare metals are (e.g. The Conference Board, 2022).

Highlighting these narratives is a voluntary and, in my eyes, necessary step in research. Research, despite scientific method used to maximize rationality and objectivity, is part of a societal, sometimes unconscious, paradigm. The questions we ask, the papers we read, the data we analyze and the indicators we use only offer part of the answer to the challenges we face as humanity. It provides only a partial view of our world, through the prism of western models and values. This thesis aims to go beyond the narratives and offer nuance in the often-simplistic considerations of important issues that are sustainability and the digital transformation.

While each chapter contains a theoretical background section emphasizing the specific research gaps it aims to fill, the introduction provides an overview of the three main building blocks of the literature I relied on in this thesis relating to digital transformation, sustainability, and strategic management. Concretely, it highlights that digital transformation and sustainability studies rely on strategic management theories, but that these fields have evolved in an isolated way. The objective of this research is to build insightful theories and guide practice by leveraging unique and novel data.

By being able to investigate the appropriate conceptual level (i.e. technological and managerial levels), the different chapters of this thesis investigate the digital transformation of companies and its interactions with strategic management and corporate sustainability (Figure 31).

More specifically, Chapter 1 bridges the gap between digital transformation and strategic management by focusing on the case of digital platforms. Filling a gap in the literature by being able to distinguish between platform owner and complementor positions, it highlights a high profusion of such technologies across all sectors and geographies, and goes beyond studying the mere decision to make or join a platform by looking at potential complementary strategies. It provides refined support to the well-established consensus that a digital technology alone cannot participate in any value creation unless coupled with strategic or managerial changes and adaptations. More precisely, it quantitatively confirms Stonig et al.'s (2022) propositions by showing that cooperation in integrating value propositions might be the necessary step towards ecosystem strategy. By system integration strategy, we mean combining one's own products or services with the ones of external partners to offer integrated value propositions. More importantly, this particular result sheds light on the necessity for firms today to open to external partnerships and align with a set of strategic alliances to create sustainable value from digital platforms technologies, a result also confirming the network-based nature of today's organizations.

While Chapter 1 bridges the gap between digital transformation and strategic management, Chapter 2 explores the relationships between the adoption of digital technologies on one side and environmental innovation on the other.

It confirms a relatively high adoption of cloud computing and Internet of Things compared with other technologies, such as artificial intelligence or smart robotics. On the environmental side, it also shows that the focus of firms today is put on process innovation through optimization, therefore minimizing the negative impacts, rather than focusing on more systemic changes at the level of business models.

In other words, this second chapter shows that the adoption of potentially disruptive technologies and practices is lagging behind more traditional and incremental ones, and that, on average, firms are only at their infancy regarding digital transformation and sustainability. Interestingly, it shows that size plays a key role in the adoption of both digital technologies and sustainability. Intended to determine the survival of firms, this clearly raises the question of whether digital transformation and sustainability is accessible to the whole population of companies, or if these transformations put large firms into a comfortable position, thereby increasing inequalities between small and large companies. Relating more to the market-based view and competitive forces (Porter, 1979), this result contributes to the strategic management literature by suggesting that, to date, large firms may be favored with the current changes, calling for a reaction from policymakers to ensure a transversal and just transition by minimizing barriers to entry.

Looking at the intersection between technologies and practices, we observed that adoption of specific technologies goes hand in hand with specific innovation actions. Concretely, chapter 2 has shown that AI is relatively more associated with business model innovation than other technologies like smart robotics or cloud computing. It also shows that, as indicated by the literature, Internet of Things constitutes the most predominant technology in terms of sustainability, as it correlates significantly with all types of innovations, be it at the level of processes, products/services or business models. Besides emphasizing heterogeneity in the relationships between digital technologies and innovation practices, this finding suggests the existence of a common latent factor that would be linked to the transformational capacity of firms driving the adoption of both sets of technologies and practices. This result emphasizes the need to align policies and strategies to efficiently and effectively integrate digital technologies and managerial practices which tackle environmental sustainability and, inspired by McElheran et al. (2022), lay the groundwork for the formal assessment of complementarities between digital technologies and environmental practices.

The third and last chapter finally integrates digital transformation and environmental sustainability with strategic management to propose an overarching strategic framework. Based on current theories at the intersection between digital transformation, sustainability and strategic management, a conceptual model made of theoretical propositions is built and illustrated by early empirical data.

It suggests organizational, operational, and communicational steps that firms must be engaged in to manage such transformational programs. These steps are composed by practices, activities, processes, and strategies that find their roots into both the resource-based view and market-based view. Indeed, while I emphasize the importance of resources such as data, which are associated with the knowledge-based view that considers information as the most valuable resource a company can have today, I also shed light on the importance of other specific resources such as digital infrastructure, specific skills, and organizational design.

Regarding the market-based view, this chapter also sheds light on the importance for firms today to move away from the linear and closed view of their firms focused on competition and embrace an ecosystem strategy characterized by a portfolio of competitive and cooperative relationships. It also highlights the importance of human beings behind such transformation and the reflection on change, emphasizing the role played by the social groups we belong to and the necessity to rely on networks of change makers both within and outside firms' boundaries. Finally, it confirms the relevance of organizational learning by suggesting a central importance of communication and transparency in such intertwined strategies for acceptability and support, as well as suggests the need for specific capabilities, especially in terms of adaptability.

Overall, it is worth noting that, while digital and sustainability issues are put at the same level politically with terms such as *twin transition*, my research suggests that sustainability should be considered as the end-goal and digital technologies as a tool that could help reach it. It goes into the same direction as research such as George & Schillebeeckx (2022) by suggesting that firms today need first to reinvent themselves and, most importantly, define a new purpose in a context where they face increasing pressure to contribute not only to the economy, but also to society and the environment.

In this context, it is of utmost importance for firms to set sustainability objectives at the highest level of their organization, the board level, and then find the relevant use cases of digital technologies to help them make progress on this new strategic orientation. It is also worth noting that, when talking about digital transformation and sustainability, the perception of firms' executives is mostly driven to positive use case or, as called in the literature, *Digital for Green* facet. The impact of digital technologies themselves is rarely discussed. However, we have seen that the direct impacts of digital technologies are similar to the ones of the aviation sector in terms of carbon emissions and that this impact is expected to rise in the near future (Freitag et al., 2021).

Besides that, solutions based on optimization and efficiency are interesting and beneficial for the environmental as long as they do not lead to rebound effects (P. H. G. Berkhout et al., 2000). In this context, one aspect that has been clearly lacking in the data we relied on is the need to integrate the literature on sufficiency and low-tech into these considerations. In periods characterized by high uncertainty on the aggregate impact of digital technologies and systemic effects, it is crucial to remain prudent when wanting to apply digital technologies to a sustainability purpose. For firms, this could translate into a comparison of solutions based on digital technologies with solutions that are not based on such technologies to integrate all impacts in the equation, not only potential optimization impacts. It also clearly emphasizes the need to develop such comprehensive frameworks that bridge the gap between two main political paradigms of sustainability emphasized in the introduction (i.e. *green growth* versus *degrowth or post growth*) and the concrete choices firms need to make.

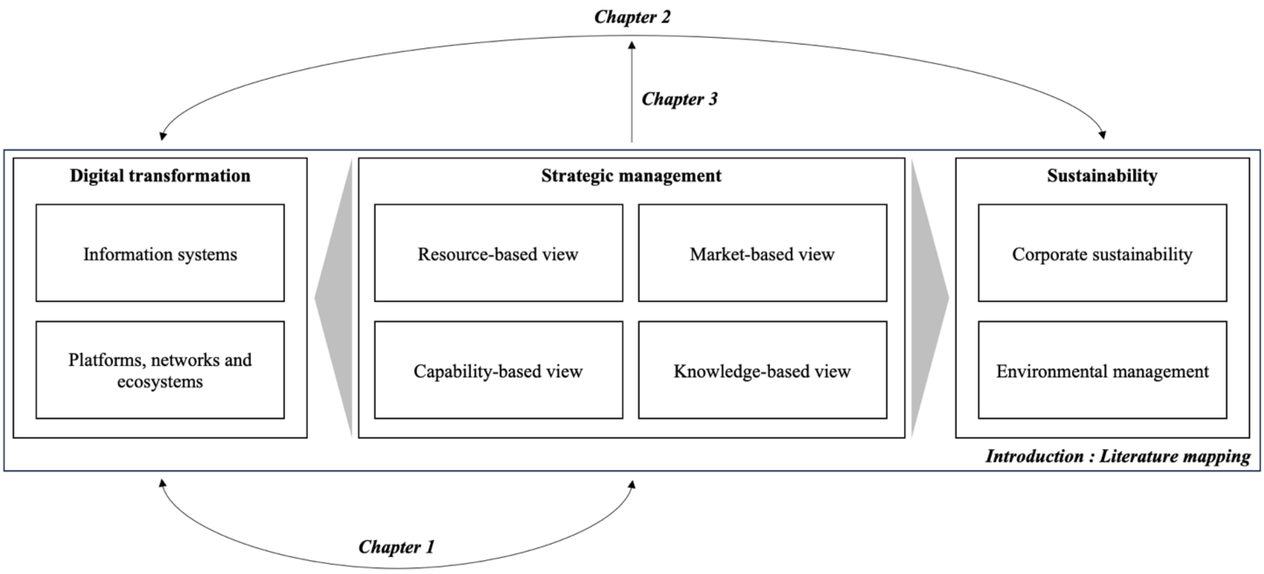


Figure 31. Literature mapping and structure of the thesis: highlighting contributions of the three chapters

1.2 Limitations

1.2.1 Data

This thesis is, as any research effort, not exempt of limitations. While exploratory on purpose, the data I use are novel, unique and tackle real-world and emerging phenomena. However, these data that have been collected through surveys and interviews present two limitations.

First, these are mostly self-declared. As indicated in the literature mapping section, my goal was to focus on the discovery of real-world problems and challenges. Being self-declared is therefore not an issue per se. Analyzing perspectives from executives of organizations enables understanding of their perception of the issues at stake, helps identify potential blind spots compared with existing knowledge on digital transformation and sustainability and allows for the compilation of a set of questions that are currently being raised on the field, for which science-based answers are expected and desirable.

However, these self-declared data may involve biases from our informants that are difficult to overcome, one of them being the social desirability bias or, put differently, the tendency from research subjects to provide desirable answers rather than responses that reflect their truths or feelings (Grimm, 2010). When asking questions that relate to the maturity of their organizations regarding digital transformation or sustainability, respondents may be tempted to be over-confident to avoid any negative judgment from the researcher or interviewer, leading to data that are overly optimistic about a certain phenomenon.

As indicated by Nederhof (1985), there are several ways of coping with social desirability bias such as forced-choice items, randomized response or in the right selection of interviewers. In the context of this research, such methods were used. For example, Chapter 2 is based on survey questions with randomized forced-choice items. While realistically there is a ranking in the options proposed for some questions, randomizing it enable to reduce the likelihood of the respondents to select the highest ranked option. Regarding interview data, we used scoring questions before diving into semi-structured questions on the management of digital transformation and sustainability in order to maximize objectivity in informants' narratives. Moreover, we decided not to record the interviews to allow for full freedom on the informants' side, knowing that he or she is, in addition to being anonymized, not recorded.

Secondly, data used throughout this thesis are cross-sectional. The cross-sectional nature of the data is inevitable when studying such an emerging and recent topic as the interactions between digital transformation and sustainability in the context of organizations. However, these types of data prevent from drawing causal interpretations from the analyses and limit the conclusions we can build upon it. When feasible, we used techniques to include some "dynamism" in the static, cross-section nature of these data. For example, when assessing the relationships between the adoption of platforms, managerial practices, and value creation in Chapter 1, we used different measures of value creation and compared both past results and future estimated results. While this does not enhance causality assessment, it allows us to rely not only on expectations of future results but also on actual results, which increases the robustness of the findings and, more importantly, the conclusions derived from these observations.

1.2.2 Theory

The second key limitation of this thesis is also related to the emerging nature of the topic as well as to the general approach of the thesis being future and practice oriented. While several calls for future and practice-oriented research have been made and are summarized in the introduction part, studying such an emerging topic has the drawback that the knowledge base is scarce and that investigating such issues may lack a theoretical backbone and structure. As indicated in the introduction, I adopted the approach of not focusing on one niche area of research or discipline, but rather remaining open in regard to the disciplines related to the topics of digital transformation and sustainability. It means that, as opposed to incremental research, I face the issue that (1) the specific literature at the intersection between digital transformation and sustainability is limited and that (2) the relationships identified between disciplines relevant to this topic are not clearly established. This approach is not as usual because it is not confined into one specific discipline, making it harder to clearly position the theoretical contributions in traditional fields of research.

1.2.3 Situated knowledge

Finally, it is crucial to emphasize the fact that this thesis has been produced by researchers originating from the western region, and that it is embedded into a dominant paradigm that, to date, has been focused on the quest of economic growth fueled by innovation. In the European Green Deal, which aims to place the environment at the center of our development, the goal is explicitly growth, even though there is no evidence to date that this approach would enable a reduction in CO_2 emissions to the desired levels (Parrique, 2019).

The questions tackled in this thesis are grounded in western debates and may involve blind spots. Among other topics, it does not deal with social conditions during the extraction of rare metals from the earth used to build devices investigated in this thesis, neither the redistribution mechanisms in place to fairly compensate countries where these resources are present. It does not raise the point of fairness in this transition, although this is necessary to be socially acceptable. It only contributes to one part of the puzzle and the reader needs to keep in mind that there are other aspects (Lange & Santarius, 2020) and other perspectives than the western one in the digital-sustainability relationships that need to be considered.

That is the reason why I am convinced by the need to produce research that is *situated* (Haraway, 1988). It means that we should reflect on the dominant paradigm we belong to, the angle we adopt, and we should be transparent about it. Research can present blindspots, and it is important when looking at science to aggregate viewpoints to build one's own opinion. We collect data, read papers, and produce research through the lens of a dominant paradigm, and it is crucial to be aware of it. Therefore, even though presented as a limitation to objectivity here, I believe that scientific methods should be increasingly coupled with a consideration on one's own *subjectivity* considering the paradigm specific research belongs to.

2 Looking at the future

2.1 Recommendations

Based on these conclusions, and with awareness of the limitations, a set of concrete recommendations towards practice can be made. These recommendations concern firms' managers, particularly incumbent ones, and policy makers.

Regarding managers, three specific recommendations can be made. First, due to regulation, stakeholder pressure and reputational risks resulting from business activities, it appears clear today that firms need to rethink their purpose and the reason why they exist. In other words, there is a need to set sustainability (i.e. environmental, social, and economic objectives) as the end goal of a business and consider digital technologies as a potential tool, among other non-technological or low-tech, to reach these objectives. The non-technical components concern strategies, processes and practices that should also be in place to derive any sustainable value from the use of such technological tools. As shown, the mere adoption of technologies may not bring the desired result, so there is a need to assess the required changes in the organization to exploit digital technologies' potential.

Second, and linked to the first recommendation, there is a need to extend the notion of performance or success to include other indicators beyond solely financial ones, as well as a need to track and validate progress regarding these indicators. As indicated by the literature, nothing gets done if not measured (George et al., 2022). Therefore, there is a need to translate the new purpose into indicators that could enable to assess the evolution of the company towards its new purpose. These indicators can relate to environmental issues, which is the focus of this thesis, notably by measuring or estimating carbon emissions from business activities and the contribution of digital technologies in its reduction, but also social indicators such as employee well-being or inclusion metrics.

Third, there is a clear need to align digital transformation with this newly defined purpose based on sustainability. To do so, we shed light on the heterogeneous potential of digital technologies for sustainability. As we have shown, digital technologies can help organizations optimize activities, redesign products or services and reinvent themselves at a more systemic level, meaning at the business model itself. Of course, specific organizational contexts will exploit the sustainability potential of digital technologies differently. While service-oriented companies such as banks in the financial sector or universities in the education sector may put more emphasis on the optimization potential of digital technologies, product-oriented or material intensive industries may look for ways to use digital technologies to better align with actors in the value chain, be it suppliers or customers, through the traceability or transparency potential it brings. By doing so, such firms could better track activities throughout the supply chain and material used in products, thereby leveraging this information to align actors in the ecosystem around circular models. In this heterogeneous situation, it will be important for managers to identify ways, notably through experimentation, to leverage specific technologies to maximize their added value regarding the objectives and indicators set in their specific organizational context. In other words, adopting a project-based approach where the sustainability contributions of digital projects shift towards such indicators can help companies getting started with the integration of digital transformation with sustainability.

Next to the recommendations directed at managers, I derive from my research a set of recommendations for policymakers, also divided into three categories.

First, and as stated in the previous paragraph, there is a clear need to align digital and sustainability indicators and make them converge. To date, there are many indicators that companies can use, and impacts are therefore reported based on the most appropriate measure to their case. There is a need to bring objectivity to that process in order to compare companies on their progress and impacts by converging towards a set of standardized and harmonized indicators. Frameworks such as SDGs set high-level direction towards sustainability, but there is an urgent need to develop common frameworks at the level of companies to direct their efforts and accompany them in assessing progress regarding environmental, social, and economic issues and impacts. In the European Union, all large companies, as well as listed companies (except listed micro-enterprises), are required to disclose information on the risks and opportunities arising from social and environmental issues. On January 5th 2023, the Corporate Sustainability Reporting Directive (CSDR) entered into force with the aim to modernize, strengthen and harmonize the rules regarding the specific social and environmental information companies need to report. Regulators have a role to play in setting the direction of economic activities towards a better balance between environmental, social, and economic risks and opportunities, so there is a need to pursue efforts in this direction when it comes to reporting and impact disclosure.

The second category specifically concerns the relationship between digital technologies and sustainability. As indicated by the results in this thesis, digital technologies can have different impacts on sustainability issues, and different scopes of impacts. As our knowledge improves on this topic, it will be crucial to direct the use of digital technologies towards use cases that have the highest positive impacts while minimizing the use of counter-productive technologies. To do so, policymakers should ensure education on these issues, as well as implement the right incentives to make the most promising technologies accessible and ensure their diffusion and adoption. As a recent example, even though not investigated in this thesis, Generative AI has become a hyped technology that companies want to experiment with today. However, there is a lack of understanding to date on how such technologies may help companies progress on the sustainability agenda. Since the environmental (e.g. Luccioni et al., 2023) and social impacts (e.g. Manyika et al., 2019) of such models is important, technological discernment is needed, and supporting education on the different impacts of such technologies is crucial. Furthermore, policymakers should also further support research and innovation programs that look at the effective implementation of the *twin transition* in order to better understand the strategic mechanisms at play, as well as track the effectiveness of such policy strategy with regard to sustainability (i.e. environmental, social and economic) impacts.

Finally, the third recommendation is related to the fact that firms' size is currently associated with a higher likelihood of both digital technologies and environmental management practices' adoption. The key concern here is that the current transformations firms need to operate might not be accessible to the whole population of companies, increasing inequalities between small and large firms and posing risks to a large number of SMEs that compose the majority of businesses' population in Europe. To date, there is already concern that the most advanced technologies are developed by tech giants (e.g. GAFAM – Google, Apple, Facebook, Amazon, Microsoft). Still relying on the recent example of Generative AI, these technological developments are led by large tech companies that have both data and computing power, as well as the funding to buy disruptive small firms. This situation already poses threats in terms of digital sovereignty, as technology is not neutral in terms of values. On top of that, we should also make sure that the adoption itself of such tools does not excessively favor large firms but remains accessible to all. There is a need to ensure the development of such technologies locally and avoid technological lock-in with global players. To do so, universities, for example, could be involved in the development of open-source technologies and models that smaller companies with potentially less technological acquisition capacities could benefit from.

2.2 Future research

Finishing this thesis makes me realize that my research raised more questions than it answers. These questions open doors for future research at the nexus between digital transformation and sustainability and can be grouped in three categories, described as follows:

First and foremost, as explained in the beginning of this thesis, the concept of sustainability is built upon three pillars which are the economy, society and the environment. This thesis has been primarily driven by the *Digital for Green* facet of sustainability, as its name indicates focusing on its environmental pillar. There is a need, in the current context, to integrate thinking on the net impact of digital technologies, meaning integrating the *Green Digital* facet. While overall assessments of direct impact of digital technologies exist at the sectorial level, as summarized by Freitag et al. (2021), it is necessary to also find ways to integrate such calculations within organizations. In other words, when thinking about digital and sustainability issues, it will be crucial to assess the global picture and not look only at the economic opportunities brought by digital technologies. The umbrella question underlying such avenue for future research is: what is the net contribution of digital technologies towards the environment?

Concretely, future research could look at how firms effectively measure or estimate the net impact of digital projects in terms of environmental or, more generally, sustainability issues. This future research could also adopt a future-oriented view on these issues based on a decision tree approach. This decision-oriented research could, based on a set of environmental, social, and economic criteria or questions, help firms assess how to take the appropriate decision regarding a digital or non-digital solution to tackle a specific business problem. In terms of methodology, researchers could consider a design science research approach where such innovative frameworks or artifacts could be co-created with the organization investigated. As mentiond by van Aken & Romme (2009), this kind of approaches could bridge the gap between theory and practice, putting research at the service of real-world problems. According to the authors, the mission of design sciences is to develop general knowledge that supports the design of solutions to field problems. It should therefore aim to develop propositions that can then be used when designing solutions to real-world field problems. Unlike social sciences or humanities that consider organizations as natural systems, design science can help us better understand organizations by considering them as action systems (van Aken & Romme, 2009) that aim to coordinate human actions to achieve goals. Referring to Kurt Lewin, Starbuck & Nystrom (1981), this could improve our understanding of organizations, following its citation "if you want to understand a system, try to change it."

Second, this thesis sheds light on a tendency today to focus on environmental issues when raising the sustainability topic. However, there are also social issues related to the use of digital technologies and there are important questions surrounding the balance between environmental, social, and economic contributions and impacts of digital technologies. Such impacts include, for example, the extraction of rare earth metals in developing countries or health issues, privacy, or even sovereignty-related issues. Sustainability issues are complex, and it will be extremely difficult to assess the net impact of digital strategies or projects along these different dimensions. One approach in this context characterized by high uncertainty would be to investigate concepts such as *precaution*, *sobriety*, *sufficiency* and *low-tech* and integrate them into strategy or policy development that relate to digital transformation. Furthermore, future research should also extend beyond the Anglo-Saxon view of the world by involving other regions and points of view. Among others, regions where rare earth metals are present, and which face important social issues attributed the global development of digital technologies and infrastructure (e.g. work conditions in the mining industry), should be better involved in research and innovation projects tackling the *twin transition* political strategy.

Secondly, this thesis lays the groundwork for complementarity assessment between digital technologies and sustainability practices or strategies. As organizations are supposed to make progress on the integration between their digital transformation and sustainability agenda in the future, new data will become available, and it will be important to assess the effective complementarities between these technologies and practices. Better understanding these complementarities will also open doors for research on capabilities, such as the specific resources and processes that firms need to secure in order for these complementarities to materialize.

Future research could therefore look at specific organizational contexts based on the type of offerings (i.e. product and/or service) and the industry it is operating in. As already suggested, the impact of technologies and practices adopted in a service-oriented organization may strongly differ from a product-oriented or material-intensive firm. Moreover, future research could also investigate the sustainability potential of recent technologies such as Generative AI to guide managers and policymakers in the adoption of such tools. In terms of methods, as also indicated in the beginning of this thesis, complementarities assessment can either be performed with correlation analyses, which is done in this thesis, and performance assessment. The latter method could be used in future research in order to assess whether the expected *twin transition* leads to the desired results or not. This performance assessment method leads me to the third and last avenue for future research this thesis introduces.

There will be a need to assess the performance effect of the adoption of digital technologies complementary to managerial practices. Still relying on the definition of sustainability, and as already emphasized, the notion of performance should be extended beyond typical indicators used by both practice and academia, such as economic value creation (revenue growth), economic value capture (profits) and overall economic productivity. The current context should force us to rethink traditional indicators and assess the performance effect of technologies coupled with practices under the light of such newly defined environmental or social indicators. This research, which could use quantitative methods as more data become available, should help us – and policymakers in particular – to estimate the aggregate effectiveness of high-level political strategies by assessing the overall impacts of digital technologies on environmental, social and economic indicators. In a context of rising pressure and reputation risks for organizations, it is crucial to realize that a firm's survival depends not only on financial health but also on progress towards sustainability.

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APPENDIX

1. Research funding

This doctoral thesis has been funded and inspired by the following research and teaching assignments:

Time period	Funding	Employer	Assignment
Core fundings			
10/2018 – 08/2020	Innoviris, Anticipate	ULB	Doctoral researcher, EPRACO project
(09/2020 – 08/2021)	*(Full time employment)*	*(ULB)*	*(Project Management Officer)*
09/2021 – 12/2021	Part-time contract + ULB Commission de classement des crédits internationaux (CCCI) funding	ULB	Research stay, Cornell university
01/2022 – 06/2024	Innoviris, Recovery and Resilience Facility FARI Institute	ULB	Researcher and lecturer • FARI Pilot project: AI strategy for the Brussels-Capital Region • FARI collaborative project: LASO project, AI innovation blueprint in hospitals • FARI Academy: introduction to AI, postgraduate
Additional projects			
2019-2020	-	-	Research project: Collecting Quantitative Data on the State of Play of Artificial Intelligence and Other New Technologies DG Connect, European Commission
2020-2021	-	-	Research project: Survey on the contribution of ICT to the environmental sustainability actions of EU enterprises

			DG Connect, European Commission
2021-2022	-	-	Research project: Data Economy DG Connect, European Commission
2021	-	-	Teaching project: ICT & Sustainability, training program for Bain & Company Solvay Executive Education
2022	-	-	Research project: Should Semiconductor Supply Chains Brace for More Turmoil? The Conference Board
2023	-	-	Research project: Digital for Green: Leveraging Digital Technologies to Improve Sustainability The Conference Board