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Vol. 42
Issue 1

JAN-APR
2024

Rediscovering local roots and interactions in management

Selected papers from Sinergie-SIMA 2023 Conference
Bari - June 29-30 2023

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FONDAZIONE CUEIM

Official Journal of Italian Society of Management

Vol. 42, Issue 1, 2024 ISSN 0393-5108 ISSN 2785-549X

sinergie

italian journal of management

Official journal of Italian Society of Management

VOL. 42 ISSUE 1 N. 123	**Rediscovering local roots and interactions in management**	JAN-APR 2024

Sinergie Italian Journal of Management is a peer-reviewed scholarly publication focusing on the principal trends in management studies.

Formerly *Sinergie rivista di studi e ricerche*

Published quarterly

Founded in 1983

ISSN 0393-5108 - ISSN 2785-549X

Open access at *www.sijm.it*

Indexed in Scopus (as from 2021), Google Scholar, ACNP, ESSPER

Sinergie Italian journal of management is published by Fondazione CUEIM, a foundation aiming to carry out and to promote scientific research, especially in the fields of business administration and of organizations management, both profit and non profit.

Sinergie Italian journal of management is the official journal of SIMA, the Scientific Society of Italian Professors of Management, whose aim is to contribute to the development and dissemination of management knowledge in the academic, economic and social fields, on an excellence basis.

The editing activity is sponsored by Consorzio Universitario di Economia Industriale e Manageriale - CUEIM - www.cueim.it

Peer reviewed journal

Journal accredited by AIDEA

Questa testata è associata a USPI Unione Stampa Periodica Italiana

Sinergie Italian Journal of Management
Via Interrato dell'Acqua Morta, 26
37129 Verona (VR), Italy
Tel. +39 045 597655
www.sijm.it

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Original Research Papers

Useful information for readers and authors

Aphorisms

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italian journal of management
Vol. 42, Issue 1, 2024

1. *The paths of loyalty are always straight.*
   (José Ortega Y Gasset)

2. *Respect comes from knowledge, and knowledge requires commitment, investment, effort.*
   (Tiziano Terzani)

3. *When you are content to be simply yourself and don't compare or compete, everyone will respect you.*
   (Lao Tzu)

4. *Education is the most powerful weapon that can be used to change the world.*
   (Nelson Mandela)

5. *None of us is as smart as all of us.*
   (Kenneth H. Blanchard)

sinergie
italian journal of management

ISSN print 0393-5108
ISSN online 2785-549X
p. 9

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How quantitative marketing and management methodology is changing

Charles Hofacker

Abstract

In this editorial I review five key trends in quantitative methodology in Marketing and Management. The trends are (1) preregistration of behavioral experiments, (2) increasing focus on sources of endogeneity in strategy research, (3) a more evidentiary approach to the strength of evidence present in a study, (4) increasing use of Bayesian statistical inference, and (5) the introduction of computer science techniques into marketing.

1. Introduction

There is a saying, told by some Department Chairs, that if you don't like a professor, you assign him or her a class in Digital Marketing or Digital Strategy. In that way, the professor has to spend weeks and weeks every year updating the class in a laborious attempt to keep up with digital practice, which changes almost weekly. Conversely, if you like a professor, you assign him or her to teach a class in Research or Methodology, neither of which, as everybody knows, has changed in 50 years. It turns out that "50 years" is not literally true. The quantitative techniques used by Marketing and Management researchers have changed, are continuing to change, and are doing so faster than many realize. It is the purpose of this editorial to describe the various ways in which such techniques are changing.

Even those who do not specialize in methodology have a need to understand these changes. There are two reasons for this. All of us, no matter what our preferred methods, need to read the papers of others. We need to have some sense that the methods employed in those papers are appropriate, and to appreciate how such methods provide the knowledge that they provide. Secondly, we need to be able to guide students, especially PhD students, in what research techniques they should learn. If we don't know the methods employed in our field, we cannot guide our students very well.

I believe there are five key current trends in quantitative Marketing and Management methodology, and these five trends form the outline of this editorial. The trends are (1) preregistration of behavioral experiments, (2) increasing focus on sources of endogeneity in strategy research, (3) a more evidentiary approach to the strength of evidence present in a study, (4) increasing use of Bayesian statistical inference, and (5) the introduction of computer science techniques into marketing. Let us now proceed with the first trend.

2. Use of Preregistration

The failure to replicate a variety of experimental discoveries in the behavioral sciences has been much commented on over the years (a recent comment can be found in Haeffel 2022). This failure has been so jarring as to be named "the replication crisis". In order to incentivize principled researcher workflow, a movement has started where researchers publicly predict how their experiment will come out (Nosek *et al.*, 2018). In some cases a journal agrees to publish the work beforehand even if the prediction is disconfirmed. One benefit of preregistration is that if the manuscript were to be published no matter what, why not simply be honest in all research activities? In addition, forcing the researcher to make a prediction a priori means that they won't be able to retroactively change their hypotheses.

In addition to the authors cited above, benefits of preregistration are discussed by Gelman and Loken (2014) who emphasize that preregistration makes sense especially for fields like consumer behavior, or human relations, where collecting new data is not terribly difficult. When data are easy to come by, results might be subject to "hidden escalation of type I errors" (Ding *et al.*, 2020), which is to say an escalated probability of wrongly rejecting a null hypothesis. In addition to this advantage, Nosek and Lindsay (2018) point to the key distinction between confirmatory and exploratory research, which can be made when research is preregistered. Nosek and Lindsay also point out that to the extent that journals agree to publish the results no matter what, publication bias can be reduced.

3. Attention to Potential Endogeneity

Endogeneity can occur whenever an independent variable is potentially correlated with the error term in a model. The implications of this correlation are rather severe: the presence of endogeneity means that we cannot draw causal conclusions. In applied fields like Marketing and Management, where the goal is to help managers figure out how to act, the inability to draw causal conclusions renders our research meaningless.

Endogeneity can occur in any research situation, but is especially likely in non-laboratory settings, which is to say with field data. Endogeneity can result from any of the following three situations: a missing independent variable that has a causally important role with respect to the dependent variable; simultaneously causation between the observed independent and dependent variables; or error in measuring the independent variable (Hill *et al.*, 2021). One of the beauties of laboratory experiments that involve random assignment of subjects to conditions is the ability to rule out endogeneity.

While there are a variety of techniques for handling endogeneity for variables that are observed and not assigned, the most popular is instrumental variables (Angrist, Imbens, and Rubin 1996). Other related techniques include the control function (Wooldridge 2015), and difference-in-differences (Varian 2016). Readable introductions to the topic of endogeneity can be found in Goldfarb, Tucker, and Wang (2022);

Hill, Johnson, Greco, O'Boyle and Walter (2021); and Jean, Deng, Kim, and Yuan (2016). While many of us have been taught that "correlation is not the same thing as causation", we often instinctively write and think about observed variables using the language of causality. It is a major trend that such loose language is being increasingly flagged by reviewers.

4. Evidentiary Approaches

At the time statistical analysis was being adopted by the social and biological sciences in the early part of the 20th century, there were three paradigms competing for attention. These were the approach of Thomas Bayes and Pierre Laplace, that of Ronald Fisher, and that of Jerzy Neyman and Egon Pearson (Fienberg 2006). The first two of these proposed that researchers should present the strength of evidence for a model or hypothesis, while the third argued that hypotheses should be rejected or not in a dichotomous fashion. Historically, the third approach was widely adopted and remains the dominant analytical framework till this day. At this time, a number of authors have proposed that we take a more "evidentiary" or continuous approach to models and hypotheses (Matthews 2011; McShane *et al.*, 2023; Wedel and Gal in press).

Dichotomous decision-making by authors and editors, contributes to what is known as publication bias (Brodeur *et al.*, 2020), otherwise known as the "file drawer problem" (McElreath and Smaldino 2015), When studies do not achieve a p-value of .05, they are placed in a file drawer and forgotten, despite the fact that such results might be telling us something important about the empirical phenomenon being investigated. Journals only publish results with p-value less than .05, leading to a biased sample of studies being published. This problem has likely contributed to the replication crisis mentioned earlier, and also causes scientists to overestimate effect sizes (Gelman 2018).

Wedel and Gal (in press) propose three principles: that authors should (1) apply their judgment to the strength of evidence that exists in a study, (2) keep in mind that p-values are sensitive to violations of model assumptions, and (3) emphasize the experimental setting rather than p-values to get a sense of the generalizability of a finding.

5. Bayesian Inference in Marketing

Recent computational breakthroughs (van Ravenzwaaij *et al.*, 2018) have led to an explosion of Bayesian methods in Marketing and Management. The advantages of Bayesian inference over traditional methods, such as those proposed by Fisher or Neyman-Pearson, include a more intuitive interpretation of research results (Wedel and Dong 2020) and axiomatic connections to optimal decision-making (Berger 1985), this latter advantage being especially appealing to fields claiming managerial relevance.

The intuitive advantage of Bayesian inference flows from Bayesians' willingness to apply the laws of probability to epistemic uncertainty, defined as uncertainty resulting from lack of knowledge. For researchers and practitioners who lack knowledge about the true value of an unknown parameter in a model, this enables direct probability statements about that unknown. By "unknown parameter", I mean the true difference between two means in an experimental condition or a regression slope in an observational study. By "direct probability statements", I mean statements of the form, "the probability that this slope is negative, given our observed data, is equal to *p*." Note how different this is from classical statistical reasoning, which goes like the following: "the probability of finding a data set for which the result is this extreme or more extreme given infinite sampling, given a specific hypothesis, is *p*."

Axiomatic connections to optimal decision-making confer many practical advantages to Bayesian reasoning. We can highlight these advantages by talking about what happens to those who do not adopt the Bayesian point of view towards unknown parameters, i. e., those who would not apply the laws of probability to epistemic uncertainty. If you do not apply those laws your behavior can be "incoherent". In essence, if your beliefs about unknown parameters do not obey the laws of probability you run the risk of inevitably losing money (Galavotti 2015).

There are many user-friendly introductions to Bayesian inference relevant to Marketing and Management scholars. Good starting points include Muthén and Asparouhov (2012); Jebb and Woo (2015); van den Bergh *et al.*, (2020); Otter (2022); and McCann and Schwab (in press).

6. The Computer Science Invasion

Over the decades, Marketing and Management have borrowed many quantitative research techniques from psychometrics and econometrics, among other fields. At this time there is an onrush of techniques entering our fields from computer science. It so happens that many of these techniques are special cases of, or applications of, Bayesian inference (van de Schoot *et al.*, 2021), which has been already covered above. Nevertheless, it seems pertinent to include techniques that have emerged from computer science as a separate and final trend. A partial list of such techniques would be data mining (Cooper and Giuffrida 2000); text mining (Humphreys and Wang 2018); machine learning (Loh 2011); big data (Vanhala *et al.*, 2020), (Antons and Breidbach 2018); and the emerging field of artificial intelligence, covered by Overgoor, Chica, Rand, and Weishampel (2019) as well as Balducci and Marinova (2018). A good review is given by Xiao (2023).

7. Conclusion

A powerful benefit of human culture is that many forms of knowledge, including academic knowledge, are cumulative, passed down from

professor to student. The cumulative nature of knowledge presents a difficult challenge for the student, however. Students are still required to be familiar with older techniques, even as we add new methodologies! The increasing methodological sophistication in business-related fields places an ever heavier burden on students, especially PhD students. What's more, articles accepted at the best journals often use more than one method. One helpful trend in the face of these challenges is that author teams are getting larger and more diverse, methods-wise. Nevertheless, it is important to at least know what the trends are within our fields. I hope this brief note is helpful in that regard.

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sinergie
italian journal of management

ISSN print 0393-5108
ISSN online 2785-549X
DOI 10.7433/s123.2024.01
pp. 11-17

Best paper

Can authenticity be built? Looking for factors that influence authentic brand activism

Received
9th March 2023
Revised
16th May 2023
Accepted
2nd January 2024

Antonella Cammarota - Francesca Avallone - Vittoria Marino
Riccardo Resciniti

Abstract

Framing of the research. *Many brands have started acting as political activists, taking public actions in favor of or against contentious issues such as immigration, police brutality, abortion, LGBTQIA + rights, or racism. Brand activism appears to be a strong paradigm change such that brand management is becoming a hot topic among scholars and companies.*

Purpose of the paper. *Authenticity is the key variable of the activist strategy; however, its characteristic elements remain unknown. Thus, this study analyses consumers' perceptions of Ben & Jerry's-an historical activist brand-to understand, first, whether it is perceived as authentic; and second, to identify possible factors contributing to authentic brand activism.*

Methodology*. Data was collected from the American Instagram profile of Ben & Jerry's. All comments were manually checked and analyzed using Infranodus. We performed text network analysis and topic modeling to gain insights from the collected text corpus as well as a users' sentiment analysis. Based on the obtained positive consumer perceptions, we then examined the official Ben & Jerry's website, attempting to detect constitutive elements of its authenticity.*

Results*. Some exciting word clusters emerging from topic modeling reveal that activism is a critical element of Ben & Jerry's consumers' evaluation, becoming a topic of discussion at the same level as the brand's products. Additionally, sentiment analysis contributes important insights, confirming the crucial relevance of authenticity in brand activism strategies. Potential constitutive elements of the authenticity of Ben & Jerry's emerged from the in-depth analysis of consumer perceptions crossed with the examination of Ben & Jerry's official website.*

Research limitations. *The study employed user comments on posts, which are declarations, not actions. This analysis was also restricted to the United States and only considered a three-year period.*

Managerial Implications. *This research offers significant insights for practitioners who look to implement activist strategies. First, although it is challenging and uncommon to develop authenticity, we confirm its crucial role in brand activism. Second, it is essential to grasp consumers' perceptions to understand how they could react to a company's activist stances. Additionally, this study reveals potential constitutive elements of authenticity in brand activism, which can be further explored in future research and applied by companies looking to enter the political arena.*

Originality of the paper. *This paper provides the groundwork for an in-depth identification of constitutive elements of authenticity in activist strategy. By examining a well-known activist brand and following positive consumer sentiments, we identified crucial and peculiar elements that could help to build authentic brand activism.*

Key words: *brand activism; authenticity; consumer perception; social media; socio-political issues*

1. Introduction

Many businesses have started embracing activism as they have become aware that corporate social responsibility (CSR) alone is no longer enough to address the wicked problems of society (Pimentel *et al.*, 2023; Sarkar and Kotler, 2018).

From this standpoint, as highlighted by Resciniti (2020), marketing is more crucial than ever in modern society since it may encourage the development of solutions to suit the needs of people, businesses, and institutions, enhancing the lives of people and society at large. This approach has also been heavily strengthened by the American Marketing Association, which has emphasized the need for research to move in this direction and has created new terms like "Mitigation in Marketing" (Mende and Scott, 2021), "Better Marketing for a Better World" (Chandy *et al.*, 2021), and "Marketing as a force for Good" (American Marketing Association, 2021).

Consumers also expect brands to play an increasingly social role (Weber *et al.*, 2023). Specifically, they believe businesses should take a more proactive approach by taking public stances on sensitive themes (Maks-Solomon and Drewry, 2020). Thus, *brand activism* refers to the phenomenon of businesses taking positions for political, social, or economic reasons (Vrendenburg *et al.*, 2020; Thürridl and Thompson, 2023). It is considered an evolution of CSR that is more in keeping with consumers' expectations and the new societal role of brands (Kotler *et al.*, 2021). Different brands are becoming activists, such as Nike supporting the Black Lives Matter movement (Schmidt *et al.*, 2022), Airbnb supporting refugees (Moreano, 2019), Gillette against toxic masculinity (Xu and Xiong, 2020), American Airlines refusing to transport children separated from their parents by immigration officials, or Lush Cosmetics promoting an anti-Israel song (Weber *et al.*, 2023).

The key variable in brand activism is *authenticity*, defined as the full coherence between the brand's activist position and its historically promoted values and between communication and its corporate practices (Vredenburg *et al.*, 2020). However, its constituent and critical elements of success remain poorly understood (Verlegh, 2023). In fact, consumer response to brand activism is still varied and unpredictable (Guha and Korschun, 2023).

Based on these premises, the purpose of this study is to understand whether a brand historically known for being an activist is perceived as authentic in its stance, and if so, to identify the crucial elements of its authenticity. We selected Ben & Jerry's, a well-known activist brand, which has built its success on the principle of social justice ever since it first opened its doors in 1978. In the content of its news releases, the company declares: "Ben & Jerry's is a company that seeks social justice and believes in a bigger calling than to merely generate profits from selling products" (Ben & Jerry's, 2017).

We analyzed consumer perceptions of Ben & Jerry's by collecting online user comments from the American Instagram profile of the brand. We chose the United States of America (USA) because it is the primary market

for Ben & Jerry's, and activism was born and developed in this country (Cammarota *et al.*, 2023). Thus, this market should be more sensitive to this theme. The research questions of this study are twofold:

RQ1: How do consumers perceive brand activism campaigns?
RQ2: Are there factors that contribute to the authenticity of a brand's activism? If so, what might they be?

The current study fills some significant gaps in the existing literature on brand activism. First, prior research confirms that consumer reactions to brand activism are still diverse and uncertain (Guha and Korschun, 2023), but they are generally negative (Bhagwat *et al.*, 2020; Mukherjee and Althuizen, 2020). By contrast, this study examines perceptions towards a well-known activist brand to determine whether authenticity is, at least in this case, validated and, in turn, how consumers respond.

Second, research on authenticity highlights its importance (Tressoldi *et al.*, 2023), its effects (Ahmad *et al.*, 2022), and some macro dimensions of its development (Vredenburg *et al.*, 2020; Sibai *et al.*, 2021), such as the brand's tone of voice (Verlegh, 2023), the alignment between the brand communication and corporate practice, and the consistency between brand values and the activist position (Vredenburg *et al.*, 2020). To the best of our knowledge, there are no studies that have identified the key elements of authentic brand activism that companies can adopt to create authenticity. Therefore, this research aims to understand consumer responses to brand activism and to identify potential elements that may strengthen the authenticity of this complicated and risky strategy.

2. Literature Background

2.1 The strategy of brand activism

Brands have begun to compete in the political arena, becoming significant activists (Korschun *et al.*, 2020). In the literature, brand activism is considered a new marketing strategy (Shoenberger *et al.*, 2021, an intersection between politics and marketing (Klostermann *et al.*, 2022), or a positioning tactic (Schmidt *et al.*, 2022).

Brand activism can be defined as "public speech or actions focused on partisan issues made by or on behalf of a company using its corporate or individual name" (Moorman, 2020). In addition to making public statements (Bhargava and Bedi, 2022), activist companies can also take stances on controversial sociopolitical issues by making financial commitments (Klostermann *et al.*, 2022), working with social movements, non-governmental organizations, and other stakeholders (Wettstein and Baur, 2016), or even by modifying their products to show support or opposition to a particular cause (Koch, 2020). Hence, through communication and practice (Kotler and Sarkar, 2018), brands express their opinions, concerns, or values in divisive public debates (Vredenburg *et al.*, 2020).

Many different variables are contributing to the growing trend of brand activism. One of the most intriguing aspects has to do with the public's

growing mistrust of institutions and governments, perceiving them as incapable or unwilling to deal with social issues (Radanielina Hita and Grégorie, 2023). As a result, companies are actively pursuing this role.

The goals of brand activism are manifold (Smaldone *et al.*, 2023); by getting involved in sensitive issues, brands hope to affect positive social change (Eilert and Cherup Nappier, 2020), not only by raising consumer awareness of these issues but also by positively influencing consumer behavior and attitudes (Villagra *et al.*, 2021). Furthermore, this strategy aims to bring the attention of the media to such issues and to pressure policymakers and institutions to address these problems (Den Hond and De Bakker, 2007). Hence, businesses use their visibility to shape public perception of these issues (Haski-Leventhal *et al.*, 2021). Brand activism could also have significant business impacts (Radanielina Hita and Grégorie, 2023; Bhagwat *et al.*, 2020). In fact, brand activism may result in significant competitive advantages in the market. First, it could be a tool to enhance the brand-consumer relationship, with potential outcomes on brand image (Hambrick and Wowak, 2021), brand reputation (Johnson *et al.*, 2022), brand attachment (Flight and Coker, 2022), consumer engagement (Kotler *et al.*, 2021), consumer loyalty (Key *et al.*, 2021), or consumer purchase intention (Zhou and Dong, 2022). Second, brand activism may also have favorable effects on the relationship between a company's employees and investors (Bhagwat *et al.*, 2020; Cadvar Aksoy *et al.*, 2023 IN BIBLIO CAVDAR).

From this standpoint, using social media to communicate with stakeholders and announce one's activist stance is essential. Brand activism is an inherently public action that manifests through advertising, public relations, and other online and offline communication (Korschun, 2021). According to numerous researchers (Bhagwat *et al.*, 2020; Warren, 2021; Pöyry and Laaksonen, 2022; Johnson *et al.*, 2022; Mukherjee and Althuizen, 2020), the main issue with brand activism is its risky nature. Taking a stand on political and social problems could result in substantial economic, financial, and reputational harm if the brands do not act in accordance with their history, mission, and values (Dodd and Supa, 2014; Vredenburg *et al.*, 2020).

2.2 Perceived authenticity and consumer perceptions of brand activism

Perceived authenticity is considered the most relevant factor in a brand activism strategy (Schmidt *et al.*, 2022; Pimentel *et al.*, 2023; Ahmad *et al.*, 2024;). Generally, consumers perceive an activist brand as authentic when its actions are truly motivated by a purpose and values (Vredenburg *et al.* 2020). Authenticity results from the consistency between a firm's actions and its online and offline communication (Vredenburg *et al.*, 2020). Authentic brands frequently set themselves apart by being sincere, steady, consistent, credible, unique, real, unattached to business interests and stakeholder oriented (Ballantyne *et al.*, 2006; Bruhn *et al.*, 2012; Yang and Battocchio, 2020; Romito *et al.*, 2023). When a brand is perceived as authentic, it increases trust, credibility, and reliability among stakeholders (Mingione *et al.*, 2020) Thus, this variable is crucial to reduce skepticism

toward the activist position of the brand (Hoppner and Vaddakkepatt, 2019; Villagra *et al.*, 2021; Ahmad *et al.*, 2022; Mirzaei *et al.*, 2022).

When brands fail to constantly align their stated values with their actual actions, they risk damaging their reputation (Siano, 2012). This issue becomes particularly evident when a brand adopts activist positions that are inconsistent with its historical values or when there is a difference between its corporate practice and communication (Mirzaei *et al.*, 2022). Such inconsistencies can lead to perceptions of inauthenticity in the brand's commitment to activism, often referred to as "woke-washing" (Sobande, 2019).

In such cases, consumers accuse businesses of utilizing this tactic as a marketing gimmick (Vredenburg *et al.*, 2020) to boost sales. It is thus essential that a brand's target audience perceive its activist positions as genuine (Ahmad *et al.*, 2022). Additionally, consumer responses to brand activism could be varied and highly fragmented, mostly because activism focuses on contentious issues on which the public strongly disagrees (Guha and Korschun, 2023); generally, these issues do not present a universal and accepted solution by all individuals (Vredenburg *et al.*, 2020). Consequently, brand activism often generates primarily negative and polarized sentiments and attitudes (Radanielina Hita and Grégorie, 2023) as compared to other initiatives like CSR or cause-related marketing, which garner more positive responses from customers (Mukherjee and Althuizen, 2020). This leads to a situation in which, on the one hand, consumers increasingly expect companies not to remain neutral on certain issues, while on the other hand, they often react negatively to brand activism by initiating a backlash (Sarkar and Kotler, 2018; Atanga *et al.*, 2022) or even boycotting brands (Neureiter and Bhattacharya, 2021; Haupt *et al.*, 2023).

A negative response from consumers can be attributed to two main factors: first, they believe the brand is inauthentic in its activist stance (Schmidt *et al.*, 2022); second, they may not share the stance and values promoted by the brand (Atanga *et al.*, 2022). In both cases, consumers could express their disapproval through boycotts or other means of dissent. This backlash can be intense (Pöyry and Laaksonen, 2022), especially when it is fueled by social media platforms (Klostermann *et al.*, 2022), which are crucial channels for spreading negative sentiment (D'Arco *et al.*, 2019).

The sentiment in user-generated content has important effects on a business' brand reputation and financial performance (Rust *et al.*, 2021). Thanks to social media platforms, today's consumers can publicly express their negative emotions through electronic word-of-mouth eWOM (Bhagwat *et al.*, 2020; Zhou and Dong, 2022), by generating firestorms (D'Arco *et al.*, 2019; Klostermann *et al.*, 2022), or even by creating anti-brand communities (Brandão and Popoli, 2021; Pöyry and Laaksonen, 2022). Some studies have also suggested that brand activism has a stronger negative impact on people who disagree with the promoted cause than it does on people who support it (Mukherjee and Althuizen, 2020).

Brands involved in sociopolitical causes can also obtain positive consumer responses and support for their activist actions (Hydock *et al.*, 2020). As previously stated, positive sentiment is primarily derived from two conditions: the brand must be perceived as authentic in its activist

stance, and it should promote values shared by its consumers. According to Johnson *et al.* (2022), almost two-thirds of consumers are willing to support or reject a brand based purely on the social ideals promoted by it.

As a result, values appear to be a key determinant of consumer decisions (Chatman, 1991), guiding their behaviors and attitudes toward a brand. Consumers tend to prefer products and brands that represent their values and identities (Hydock *et al.*, 2020). By associating with identity-coherent brands, consumers can express a version of their self-concepts (Reed *et al.*, 2012; Bertoli *et al.*, 2019), which also strengthens the consumer-brand relationship. As highlighted by Hydock *et al.* (2020), consumers identify with brands that are in political alignment and disidentify with brands that are in political misalignment with their values. Consequently, a brand that is perceived as authentic in its activist commitment could possibly generate important benefits not only for civil society but also for the company itself.

3. Methodology

3.1 Research Design: the case of Ben & Jerry's

To the best of our knowledge, Ben & Jerry's, the fourth most popular ice cream brand worldwide (Zhou, 2016), is a *Top-of-Mind brand* when it comes to activism. Because of this, it lends itself to being a fascinating case study from which to better understand the phenomenon of brand activism. Since its debut in 1978, this brand has distinguished itself for its social commitment (Ciszek and Logan, 2018). This is due to its operating philosophy of *capitalism infused with activism* (Gelles, 2015). The brand actively supports several issues, including police brutality, legalizing marijuana, LGBTQIA+ rights, and abortion. In fact, on October 6, 2016, Ben & Jerry's made a contentious public statement on its social media sites endorsing the polarizing Black Lives Matter campaign. The brand's posts are often controversial, sharp, and specific; we report a Ben & Jerry's Instagram post in Figure 1.

Fig. 1: Ben & Jerry's Instagram post against policy brutality

Source: Ben & Jerry's Official Instagram Profile

Additionally, in 2009, the business temporarily changed its name to Chubby Hubby to honor the passage of the same-sex marriage statute in Vermont where Ben & Jerry's headquarters are located (Wettstein and Baur, 2016). The underlying principles and vision of this company, which are focused on the social role that Ben & Jerry's intends to play in society, are the key success factors of its activism.

3.2 Research method

Our research approach involved performing exploratory research using content analysis, as the topic examined is still relatively unexplored and needs to be structured based on more thorough investigation (D'Arco *et al.*, 2019). We used a case study methodology that allows researchers to achieve a holistic picture of a phenomenon (Zarestky, 2023) and is more suited to the real-business context (Yin, 1984). Focusing on a single case might be appropriate when dealing with unique or exceptional cases, despite its inherent limitations (Siggelkow, 2007).

Ben & Jerry's is a distinguishable brand that was established with a powerful activist spirit and mission (Ciszek and Logan, 2018). Due to its distinctive nature, this single-case study offers alternative viewpoints that differ from the prevailing paradigm (Siggelkow, 2007; Retolaza, 2017), particularly on negative perceptions of activist brands by consumers (Neureiter and Bhattacharya, 2021; Atanga *et al.*, 2022; Pöyry and Laaksonen, 2022; Radanielina Hita and Grégorie, 2023). Lastly, single-case data analysis techniques might facilitate deeper insights and more accurate, data-based findings (Ninci, 2019). They are particularly effective in specific situations, depending on the aims and types of data (Manolov *et al.*, 2017).

This approach allowed us to perform a deep content analysis of scraped comments posted on Ben & Jerry's U.S. Instagram profile to identify how consumers perceive the company's activism.

According to Marino *et al.* (2020), online scraping and data analysis offer marketing researchers and practitioners a unique opportunity to analyze people, communities, and society. Social media constitutes a diverse and wide-ranging source of information. Instagram was chosen as the platform for data collection because it provided more data in the form of comments than other social media platforms. Data was scraped from the company's official US Instagram profile, ensuring compliance with legal standards and respect for user privacy (Walker and Kaye, 2022). About 58k comments in total were gathered from all the posts between 2020 and 2022, with 12k for 2020, 31k for 2021, and 15k for 2022. All personally identifiable information was anonymized in the dataset. After conducting a preliminary analysis of the purified dataset, we selected all comments to thoroughly examine activism-related themes, ensuring a comprehensive and unbiased analysis. Next, we uploaded the datasets to Infranodus to perform a text network analysis and a sentiment analysis for each year. We conducted an automatic content analysis because of its elevated dependability and accuracy as well as its reasonable level of efficiency in contrast to the efficiency of manual methods, its high validity, and its high reliability (Lee *et al.*, 2020). Infranodus groups thematically related

words using graph theory instead of a probability distribution (D'Arco *et al.*, 2023). This approach assigns words to distinct groups, resulting in the emergence of main topical clusters. With the aid of sophisticated visualization tools, which can be used for both quantitative and qualitative research, this application of graph theory helps to better understand the structure of textual discourse (Paranyushkin, 2019).

The main goal was to obtain a more profound and wide-ranging description of the phenomenon, identifying not only consumer perceptions through sentiment analysis but also possible factors that could have affected the consumer's perceived authenticity of the brand. For this purpose, the topical clusters derived from topic modeling and keyword extraction helped us to better understand Ben & Jerry's activism and the variables that are most influential with consumers. After the data analysis, we proceeded with the interpretation stage (Izzo and Storlazzi, 2021) by matching the results with a further investigation of Ben & Jerry's official website to identify elements that contribute to its authenticity.

4. Findings

Consumer responses to brand activism on social media platforms seem to depend on multiple factors, such as post content, reporting period, and the issues supported. In our analysis, we examined user comments on the American Instagram profile of Ben & Jerry's for the three years of 2020, 2021, and 2022.

4.1 Topics and relations

By means of topic modeling, we identified the main clusters that emerged from each year's comments. Four main clusters were found in 2020: Ben & Jerry's (20%), Chunky Flavors (19%), Political Ice Cream (17%), and Cheesecake Bliss (14%).

Table 1 shows the main keywords in the *political ice cream cluster* regarding activist topics. The keywords include "Biden", "people", "political", "joe", "white", "country", "justice", "vote", "issue", "Trump", "call", and "support". By analyzing the relationships among the most frequently used words, the top twenty words related to brand activism were identified with their targets, occurrences, weight, and betweenness. "Weight" measures the strength of connection between two nodes in a graph. It signifies frequency or intensity of the link. In contrast, "betweenness" identifies frequently occurring nodes on the shortest paths between any two nodes in the network (Paranyushkin, 2019).

In 2021, the top clusters identified were: Anti-racism Movement (29%), Israel-Palestine Conflict (21%), Vegan Ice Cream (21%), and Palestine Advocacy (12%).

Some of the words identified for the *Anti-racism movement cluster* are "racist", "movement", "policy", "Jewish", "hate", "history", "American", and "standing". For this cluster, we specifically alluded to the Black Lives Matter Movement, which drew a wide range of reactions, including widespread

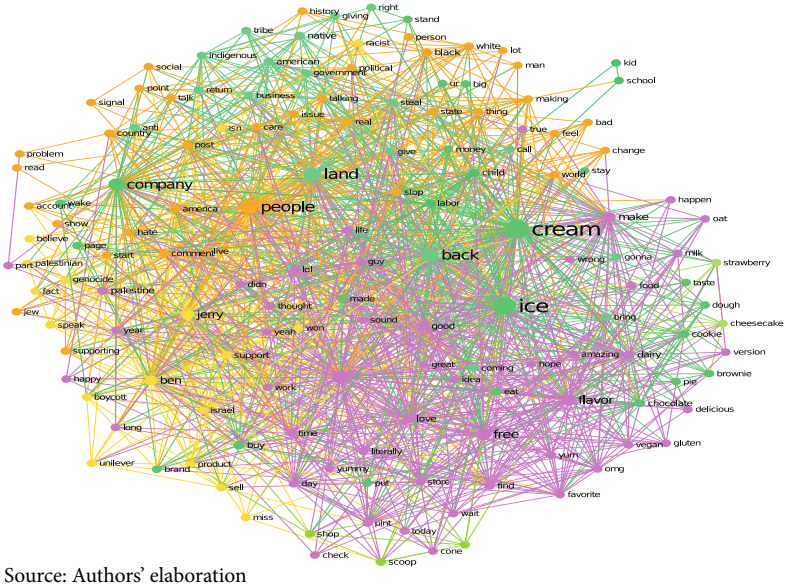
support, confusion, honest inquiries, and some hostility. For the clusters *Israel-Palestine Conflict and Palestine Advocacy,* words are "Palestine", "free", "state", "support", and "shame", while for *Ben & Jerry's Boycott*, they are "Unilever", "boycott", "lie", and "anti-Semitic". In 2021, when Unilever made the decision to boycott the sale of its products in Israel, Ben & Jerry's decided to continue to operate there and in the occupied territories of the West Bank. The cluster clearly shows the reactions and concerns shown by consumers regarding this controversial and risky brand decision. Figure 2 shows the main words that emerged from 2021.

Tab. 1: Keyword Relations Analysis 2020

Source	Target	Occurrences	Weight	Betweenness
Biden	Harris	8	64	0.0134
vegan	version	14	41	0.0002
@benandjerrys	vote	9	39	0.7973
free	flavour	14	33	0.1975
love	company	14	33	0.2600
@benandjerrys	real	8	27	0.7576
free	version	9	27	0.0134
live	matter	9	27	0.0127
black	people	8	27	0.0419
love	dairy	10	26	0.2841
flavour	vegan	13	26	0.1843
buy	ben	9	26	0.0720
vote	Trump	10	26	0.0397
@benandjerrys	vegan	8	24	0.7577
white	people	7	23	0.0167

Source: Authors' elaboration

Fig. 2: Infranodus topic modelling results from 2021



Source: Authors' elaboration

Table 2 reports the top twenty words related to brand activism in 2021, which were identified based on the analysis of the relationships among the most frequently used words, with their targets, occurrences, weights, and betweenness.

Tab. 2: Keyword Relations Analysis 2021

Source	Target	Occurrences	Weight	Betweenness
free	Palestine	44	132	0.2886
human	right	10	29	0.0137
speak	Palestine	11	27	0.2292
boycott	ben	8	22	0.1205
@benandjerrys	Palestine	5	18	0.6817
illegal	Israel	6	18	0.0172
support	Palestine	6	14	0.2499
support	state	5	14	0.0524
boycott	jerry	6	12	0.0369
stop	selling	4	12	0.0081
social	justice	4	12	0.0042
supporting	Palestine	4	11	0.2474
law	racist	4	10	0.0022
occupied	territory	4	10	0.0028

Source: Authors' elaboration

The clusters Corporate Abuse (18%), Political Activism (16%), Spiritual Reflection (16%), and Baked Treats (12%) were identified for 2022. Table 3 highlights the main words for this year.

Tab. 3: Keyword Relations Analysis 2022

Source	Target	Occurrences	Weight	Betweenness
cream	Israel	3	9	0.2187
people	day	4	8	0.0129
making	free	4	8	0.0199
love	bring	4	8	0.4322
vegan	food	2	6	0.0020
stay	politic	2	5	0.0004
abuse	murder	2	5	0.0005
abuse	rape	2	4	0.0008
vote	realise	2	4	0.0007
georgia	big	1	4	0.0041
selling	Israel	3	4	0.0004
rape	murder	1	3	0.0013
murder	animal	1	3	0.0005
animal	company	1	3	0.0130

Source: Authors' elaboration

Specifically, some of the most frequently used words for the *Corporate Abuse cluster* are "murder", "animal", "woman", "rape", "Iran", and "slavery". For the *Political Activism cluster,* the most frequently used words are "people", "vote", "politic", and "choice"; while for *Spiritual Reflection*, the words are "political", "police", and "moral". The Corporate Abuse cluster is related to several issues highlighted by consumers. First, it is associated with comments regarding Ben & Jerry's position on selling vegan products. Second, it is also associated with Ben & Jerry's position on the Iranian situation. In fact, the company was accused by many followers of not being active enough on this topic.

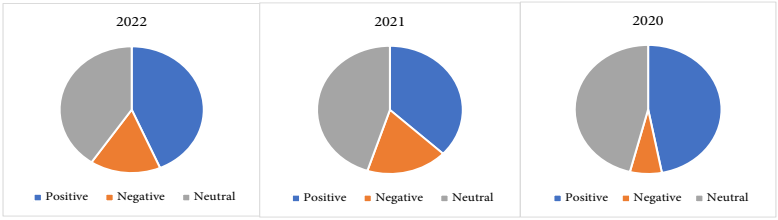
4.2 Sentiment analysis of consumer responses

Sentiment detected from comments over the three years was also analyzed and is reported in Figure 3. Consumer responses were classified into positive, negative, and neutral by using Infranodus.

In 2022, positive sentiment rose to 44%, negative to 16%, and neutral to 41%. In 2021 and 2020, a higher neutral sentiment was found than in 2022. In 2021, there was 45% neutrality, 37% positivity, and 18% negativity. In 2020, there was 47% positivity, 7% negativity and 46% neutrality.

The most pertinent remarks in relation to topical clusters on political, economic, and social issues are included here. They demonstrate how consumers react to the activism of Ben & Jerry's.

Fig. 3: Sentiment Analysis (2020, 2021, 2022)



Source: Author's elaboration

Table 4 shows some example comments for each of the identified clusters.

Tab. 4: Comments analysis of the main clusters

MAIN CLUSTERS	COMMENTS	SOURCE	SENTIMENT
Racial Justice	Use your platform to address settler colonialism in Palestine. For a year you've been speaking up on racial justice and human rights.	Instagram	Negative
Palestine Advocacy	@benandjerrys why do you have a factory in an illegal Israel settlement in occupied Palestine?	Instagram	Negative
	stop supporting ethnic cleansing and putting on a fake woke veneer. FREE PALESTINE		Negative
	Ben & Jerry has been silent on their corporate stand against the Israeli government ethnic cleansing of Palestine.		Negative
Ben & Jerry's Boycott	Every occupying state must be boycotted just as we must boycott the United States that conquered its territory from the Indians. #BoycottUSA	Instagram	Neutral
Corporate Abuse	Is all oppression connected? Including the oppression, abuse, rape, and murder of animals. Your company profits off of and enables the dairy industry: a cruel, oppressive, abusive, and totally unnecessary entity.	Instagram	Negative
	Racism, ableism, homophobia, transphobia, misogyny, and speciesism is everything wrong with the world. See YOUR part in it, Ben & Jerry?s? The hypocrisy is insane.		Negative
	Thank you for supporting Israel!		Positive
	Thank you for all that you do and advocate for!! Love your products and support your company!		Positive
	You guys are the best. Truly an organisation I want to financially support and would love to work for.		Positive
Political Activism	WARNOCK ALL THE WAY???????? GO GEORGIA!!!!!!	Instagram	Neutral
	Come on Georgia we need you to show up and show out???????? #votewarnock		Neutral
	It's crystal clear their is a good candidate and a terrible candidate.		Neutral
	Choose wisely Georgia! The world is watching you.		Neutral
	GO VOTE! And Vote For Warnock!		Neutral
	Vote red save Georgia and the country!		Neutral
	Oh great political Ice cream		Positive
	Aren't you an ice cream company? Stay out politics. Your responsibility is to make money for your shareholders.		Negative
Spiritual Reflection	I love your moral compass.	Instagram	Positive
	White Russian for the love of god and donate proceeds to the Ukraine.		Neutral
	I'm a teacher and I can tell you a lot is at stake this November! Republicans want to take away puberty blockers, cross sex hormones and even gender affirming surgery! this is the most important election of our lifetime!		Neutral
	Love this and yes please vote.		Positive

Source: Authors' elaboration

Based on the results that emerged from the analysis of user comments, we then analyzed the official communication on Ben & Jerry's website. In particular, the comments analyzed concerned the social initiatives carried out by the brand: *Voting Rights, Racial Justice, LGBTQ+ Rights, Climate Justice*, and *Campaign Finance Reform*. These five areas of intervention are

clearly and precisely addressed on the official Ben & Jerry's website; they appear to be macro topics on which the brand intervenes by supporting small and specific causes pertaining to each area.

Through the analysis of the main topics covered and consumer sentiment, significant differences in the three years were discovered. First, it seems that Ben & Jerry's posts have become a space for discussing current issues in line with the brand's central values.

In 2020, an intense discussion on voting rights emerged, with particular reference to that year's election; for example, one relation identified "@ benandjerrys" as the source and vote as the "target" and several keywords, such as "Biden" and "Trump". In 2021, however, an increased focus on social and racial justice was detected. The Israel-Palestinian crisis attracted increased attention through polarized comments encouraging support and action for human rights. The same themes were also identified in 2022, focusing on brand political activism. With respect to these themes, consumer perceptions were varied, leaving room for greater neutrality in the years 2020 and 2021. In general, there was a lower percentage of negative comments, and this is a particularly interesting result in the context of brand activism strategy. After a deeper analysis of the comments, it was found that followers tended to find that arguing their positions on particular topics of interest was more challenging than giving their own assessment of the brand's activist actions, thereby leaving room for greater neutrality of sentiment. Over the course of the three years, many more positive comments were noted.

On issues for which the brand does not advocate, consumers reacted negatively, expecting and demanding a greater degree of intervention. This could imply that the brand is recognized as an activist and that its stance is perceived as authentic. Although there is greater positivity of comments, negative comments were noted in 2021 and 2022 related to the brand's response to Unilever's decision to sell the Ben & Jerry's ice cream business in Israel to a local licensee in violation of the agreement between the two companies. Despite this, it is evident how authentic Ben & Jerry's is perceived in its decisions, addressing controversial issues without abandoning its values.

4.3 Potential constitutive elements of authenticity

We examined the company's social media platform as well as the official website to identify potential factors that could explain consumers' perceived authenticity of Ben & Jerry's activism.

We identified the following factors that could contribute to the company's authenticity. First, a strong *engagement strategy* based on "take action" and "call to take action", reports on both social media, and the brand's official website. The brand adopts a *process of educating* consumers by making them not only sensitive to specific issues but also aware of what might be the best concrete and immediate actions to implement.

Second, the brand's *continuity* in promoting human rights, social and economic justice, and environmental protection. From its inception, the brand has been guided by its core values and by giving its products a hidden purpose.

Third, its commitment to promoting activism is well understood and documented on its website and in previous years' posts, ensuring *transparency*.

Fourth, Ben & Jerry's has a strong familiarity with U.S. social issues; thus, there is a high consideration of controversial issues related to the *proximity* of the territory.

Finally, this brand takes a stance on *highly controversial* and *specific issues*, not limiting itself to hot media topics of the moment but ensuring continuity in promoting its core values.

5. Conclusion

5.1 Discussion and theoretical implications

The findings provide substantial implications for the academic debate about consumer response to brand activism and the construction of the authenticity variable in activist strategy. Brand activism is a burly shift in the management paradigm (Andersen and Johansen, 2023). However, we still need to understand whether activism can be adopted by all brands, how to predict consumer responses and, above all, whether authentic brand activism can be built. This study tried to establish the groundwork in this direction by identifying consumer perceptions of Ben & Jerry's activism and, in the case of favorable or neutral responses, detecting potential elements that may have contributed to the brand's authenticity in its activist stance.

Previous literature has highlighted that brand activism results in unfavorable reactions, hate speech, and even anti-brand actions (Pöyry and Laaksonen, 2022; Atanga *et al.*, 2022; Cammarota *et al.*, 2022). By contrast, our study shows that consumer responses to Ben & Jerry's activist communication are positive and shared by users, who perceive the brand as particularly authentic in its activist positions. According to Mukherjee and Althuizen (2020), boycott declarations and unfavorable eWOMs may arise from brand activism. Instead, our findings show that consumers not only make brief remarks but also tend to argue their online comments. Specifically, Ben & Jerry's posts look like *microblogs* where users participate in conversations about the social causes the company supports. These conversations occur not just between consumers and brands but also between consumers themselves, thus fueling a virtuous engagement process on social issues.

Lastly, studies on brand activism have also been conducted in the United States (Livas *et al.*, 2023) and have revealed negative responses. Conversely, our research reports a tiny percentage of negative user comments resulting from adverse reactions to Ben & Jerry's activist communication because the brand has not taken positions on issues that the user thinks are relevant. Additional evidence of how much consumers appreciate the activist commitment of this brand is that they expect it to take activist positions on different social issues.

Based on the positive consumer sentiment toward the activism of Ben & Jerry's, this study confirms the previous literature on the critical role of

authenticity in brand activism (Vredenburg *et al.*, 2020; Key *et al.*, 2021; Schmidt *et al.*, 2022; Hesse *et al.*, 2022; Ahmad *et al.*, 2024). However, from this perspective, our research offers an innovative implication for authentic brand activism. Prior studies have highlighted that authenticity is primarily determined by three dimensions (Vredenburg *et al.*, 2020) and is a matter of morality (Sibai *et al.*, 2021), The three dimensions of authenticity are the alignment between the brand's values and the activist stand, business practices and communication, and tone of voice (Vredenburg *et al.*, 2020; Verlegh, 2023). However, Verlegh (2023) pointed out that little is known about the probable construction of this widely recognized crucial construct.

Our article contributes to closing this gap by identifying potential constitutive elements of authenticity extrapolated from Ben & Jerry's social profile and official website. First, we argue that an activist brand's authenticity stems from its ongoing activism, a position on highly specific, contentious, and near issues that matter to the brand's target audience. For instance, the findings show that Ben & Jerry's adopts stances on social concerns consistent with the events and sensitivity of the American context. Topics about the "right to vote" for the US elections dominated in 2020, while "Human rights and Palestine" were hot topics in 2021. In addition, Ben & Jerry's has always taken a firm stance. "Political activism" with terms like *women, Iran,* and *choice* appears in 2022; this is likely due to the American Supreme Court's 2022 ruling on the right to an abortion as well as the terrible state of Iranian women.

Transparency is also one of this brand's main strengths, which helps to create its authenticity. All its activist commitments are clearly stated, illustrated, and documented on the brand's official website. This is accomplished through appealing storytelling that calls for consumer action and serves as both an informative and, notably, engaging process.

Thus, we argue that not all activist brands are perceived to be inauthentic, attacked by negative eWOMs, firestorms, or boycotted. There are brands like Ben & Jerry's whose market positioning, competitive advantage, and, perhaps, even the loyalty of its consumers depends precisely on it being an activist brand.

5.2 Managerial implications

This research offers interesting implications for activist companies, particularly those desiring to enter the political sphere. First, it is confirmed that authenticity is an essential antecedent for favorable consumer responses. Thus, it is likely that the activist strategy will fail if brands are not perceived as authentic by their consumers.

Second, companies should pay close attention to how consumers react to activist posts, not only to their own but also those of other companies, such as their competitors. By doing this, businesses will be better equipped to predict the mood and responses of consumers and avoid potential hazardous circumstances or inappropriate plans of action.

Third, we suggest that both the activist communication on the social media platform and the official website of the brands should be fully consistent. Our findings reveal that communication on social media should

be more direct, immediate, and faster, while institutional communication should be more explanatory, educational, and rigorous. However, both need to be in line with the language, issues, and goals of activism.

Lastly, our research identifies some potential authenticity building blocks that activist brands may put to the test. Beyond complete coherence in communication, we recommend: (1) a robust engagement strategy based on a consumer awareness process; (2) continuous, rather than intermittent, activism; (3) maximum transparency regarding brand actions, goal-achievement processes, and involved actors; (4) closeness to the topic so that it is felt by consumers; and (5) the issue should be specific and not general.

5.3 Limitations and future research

This article has some limitations that provide directions for further research. First, the current study is based on user comments, treated as declarations. Given that consumers frequently declare to boycott or support activist brands, we are not able to investigate whether any boycott declarations translate into consumer actions. Thus, future research should adopt other quantitative methods, such as surveys, to test intentions or experiments and conjoint analysis to test consumer behavior.

Second, we only looked at Ben & Jerry's American profile throughout a three-year period. Further studies ought to explore whether this positive consumer response exists in markets other than the primary one for Ben & Jerry's, such as the United Kingdom, Italy, Australia, or New Zealand; additionally, a larger time span should be considered to increase the data's generalizability.

Finally, the potential constitutive elements of the authenticity detected from Ben & Jerry's will have to be analyzed and studied in detail by future research because Ben & Jerry's can be an interesting case study of authentic brand activism. Specifically, we suggest that future research should investigate not so much the importance of authenticity in brand activism strategy but rather how to generate this authenticity, which brands may or may not be activists, and the elements upon which this corporate decision should be made. This is crucial to understanding if a brand can engage in activism and how it can do so, considering that brand activism is not a possible action for all brands (Korschun, 2021).

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sinergie
italian journal of management

ISSN 0393-5108
ISSN 2785-549X
DOI 10.7433/s123.2024.02
pp. 21-42

FONDAZIONE CUEIM

S I M A
Italian Society of MANAGEMENT

Selected papers

How sustainable is smart farming? The contribution of service platforms to innovate Italian agribusinesses[1]

Received
28th March 2023
Revised
1st June 2023
Accepted
5th February 2024

Maria Vincenza Ciasullo - Marco Savastano
Alexander Douglas - Miriana Ferrara - Simone Fiorentino

Abstract

Framing of the research. *The agrifood industry needs to embrace digitalization by strategically innovating toward ecological transition and sustainable growth. A conceptual framework, empirically informed, is proposed, and a mixed-methods approach in the Italian wineries' context is adopted.*

Purpose of the paper. *This paper aims to analyze how the sustainability of agribusinesses, especially wine producers, could be improved by implementing precision agricultural systems in place of conventional ones with the support of a digital service provider.*

Methodology*. A sequential mixed methods approach based on both secondary and primary data was conducted. The quantitative analysis focused on a cost-benefit comparison between conventional versus 4.0 wineries. The qualitative analysis was performed through a multiple case study, focusing on the interplay between the service provider and the wineries. Ten interviews were conducted with both actors.*

Results*. The results contribute to the literature by enriching the conceptual framework proposed and updated with empirical evidence. It describes dimensions and relationships that enable the actors involved in reaching higher sustainability outcomes at the firm and network levels.*

Research limitations. *The limited investigated sample, based on a low number of interviews, does not allow a consistent generalization of the results.*

Managerial implications. *Evidence from the case studies can inform both practitioners and policymakers about best practices and process innovation activities, which can increase shared value creation in the agrifood ecosystem.*

Originality of the paper. *This is one of the first studies to take into consideration a relevant topic, still poorly investigated, by deepening how a digital service provider supports the wineries' innovation toward sustainable outcomes.*

Key words: *digital servitization; service platform; precision agriculture systems; winery organizations; sustainable ecosystem; smart farming*

1. Introduction

The increasing number of environmental and social challenges evolving worldwide (e.g., climate change, energy demand, nutrition, etc.),

[1] Acknowledgement: We would like to thank the company Elaisian Srl for the support in terms of data and technical knowledge.

also speeded by the recent post-COVID-19 pandemic effects, restored the debate about the need for a more sustainable way of doing business. Nowadays, the topics of sustainability and sustainable development are top priorities in global political and academic research. This is evident through the continued launch of new blueprints (e.g., millennium development goals to sustainable development goals) by intergovernmental organizations (e.g., the United Nations) to address the world's growing problems. At the same time, in contemporary research, there is a growing attention to embracing innovative solutions; particularly, there is the need to explore how organizations can reorient their strategies and adapt their business processes to address sustainability at corporate, societal, and environmental levels.

Among the various sectors, the agrifood industry is more vulnerable to global climate change, and it is expected to face several challenges based on some potentially risky global trends (De Clercq *et al.*, 2018). The growing number of people, estimated to reach approximately ten billion by 2050, corresponds to greater demand and, in turn, increased food production.

The use of natural resources, including farmlands and water, is highly unsustainable. The practices of deforestation, inadequate fallow periods, overuse of water resources, vegetation overcutting, and fast urbanization, among others, reduce the efficiency and effectiveness of agricultural management. In addition, inefficient farm machinery practices waste large amounts of energy resources. According to the Intergovernmental Panel on Climate Change (IPCC), agriculture is one of the main sources of greenhouse gases (GHGs), contributing to the largest share of global methane and nitrous oxide emissions (IPCC, 2022). In turn, the various side effects of climate change negatively affect agriculture and food production systems. In addition, the growing percentage of food waste represents a massive market inefficiency as well as another environmental and societal issue. Given these arguments, embracing sustainability in the agricultural sector is urgent for climate change mitigation, natural resources enhancement, and human health preservation.

The European Green Deal supports the key role of digitalization for ecological transition and sustainable growth. The EU Commission pushes to invest in new digital technologies for agriculture activities, aiming to increase the sustainability and competitiveness of the sector while enhancing the conditions of farmers by simplifying their daily work (Savastano *et al.*, 2022).

Digital transformation can be an important driver of sustainability; indeed, following the Industry 4.0 paradigm, European agriculture is experiencing a digital revolution. Technological innovations such as the Internet of Things (IoT), artificial intelligence (AI), smart autonomous robotics, decision support systems (DSS), and blockchain applications enable the possibility to collect and analyze large amounts of data, which supports business actors in making better-informed decisions for optimizing processes and products (Hrustek, 2020). Likewise, Industry 4.0, precision agriculture systems, also known as smart farming or agriculture 4.0, integrate digital technologies into business processes to raise productivity levels and develop new digital ecosystems (Trivelli *et*

al., 2019). The collected data through in-field sensors, drones, and satellites allows farmers to monitor crops and livestock. These systems help improve crop yields, reduce costs, including labor costs, and optimize process inputs (Tantalaki *et al.*, 2019). At the same time, smart systems can lead to increased profitability, improved work safety, and reduced environmental impacts of farming management, thus contributing to the sustainability of agricultural production (Barnes *et al.*, 2019).

However, despite some important investments and financial options to foster a smooth digital transition, their diffusion proceeds slowly, particularly in the agricultural business sector (Sarri *et al.*, 2020). The transition to digitalization seems far from easy, and firms undergo a process of profound changes that require a deep reconfiguration of the business structure and related ecosystems. More research about how farming businesses could strategically exploit digital technologies to pursue sustainable goals is demanded. Particularly, the literature contends that the application and diffusion of complex technologies such as precision agriculture systems cause much uncertainty among farming businesses. They struggle with the lack of human, territorial, and knowledge resources for successfully embracing digital transformation. Then, the involvement of different actors who support their practical adoption and implementation is required (Smania *et al.*, 2022). Indeed, introducing disruptive innovations in such a traditional sector may lead to the upheaval of a prior organization, especially in small businesses, requiring digital skills and related capabilities and novel configurations of sustainable business models. Theoretically, scant literature addresses digital transformation in agricultural settings by combining a socio-technical perspective (Moretti *et al.*, 2023). Scholars underline that digital technologies do not deliver as much value in practice as providers promise, calling for a reformulation from the user's perspective (Silvi *et al.*, 2021). Against this backdrop, the study proposes Digital Servitization (DS) as both a theoretical lens and a practical solution able to valorize users' needs by affording both technological and social facets. DS has been defined as digital-enabled services relying on technological components embedded in physical products (PSSs) that enable new ways of value creation by combining tangible and intangible elements (Ciasullo *et al.*, 2021; Schiavone *et al.*, 2022). Particularly, knowledge acquisition and inter-firm collaborations assume a key role in shaping new digital modalities of innovation towards sustainability. Then, DS allows for the enhancement and integration of socio-technical systems, focusing on the development, diffusion, and use of digital solutions. As previously stated, a lack of digital skills in acquiring technical knowledge limits farming actors ability to exploit the strategic potential of digitalization for achieving sustainable goals. Accordingly, this paper assumes that a digital service platform could support farming businesses both in acquiring new knowledge from data and in activating and nurturing collaborations with networked actors able to frame a digital sustainability-oriented ecosystem.

Then, the leading research question arises as follows:

RQ: *How do digital service platforms allow farming businesses to achieve sustainability gains?*

Moreover, to deepen the interconnected socio-technical components of the study, the following sub-questions emerge:

RQ1.1: *What are the effects of precision agricultural systems on farming businesses' operations management?*

RQ1.2: *How does the interaction between digital service platforms and farming businesses contribute to achieving sustainable outcomes?*

Empirically, the study focuses on the Italian wine sector due to its relevance in terms of sales and product quality (Stanco *et al.*, 2020), as well as the recent investments in innovation for smarter and greener production processes, along with renewed organizational and managerial models (Nazzaro *et al.*, 2022). Methodologically, the research design embraces a mixed-methods approach based on sequential quantitative and qualitative data analysis (Tashakkori and Creswell, 2007).

The paper is structured as follows: in Section 2, the theoretical background is analyzed, and a framework is proposed. Section 3 illustrates the research methodology. Sections 4 and 5 provide the results and the discussion, highlighting the contributions of the study. Section 6 underlines theoretical and managerial implications, and Section 7 proposes concluding remarks, limitations, and future research.

2. Literature Review

2.1 Digital transition for sustainability in the agri-food sector

The digital transition of the agrifood sector depends on paradigm shifts throughout the decades (Dayioğlua *et al.*, 2021). Indeed, if Agriculture 1.0 referred to the conventional agricultural age, where basic instruments were utilized in agricultural activities, Agriculture 2.0 developed when industrialization arose. In this scenario, farmers operated agricultural machinery, and plenty of chemicals were used, so productivity and efficiency significantly increased. However, this considerable advancement has provoked unfavorable side effects such as field chemical pollution, ecological environment degradation, and excessive power use, affecting an overall loss of diversity, both biological and cultural. The Green Revolution in the 20th century accomplished the Agriculture 3.0 era, which allowed both to automate processes and to reduce the use of chemicals. The development of cutting-edge technologies has initiated the agri-tech paradigm of Agriculture 4.0, also known as smart agriculture. It represents the latest evolution in precision agriculture and involves the mentioned technological innovations of Industry 4.0, combined with sensors, robots, and AI, especially machine learning (ML) techniques, for advanced data analysis (Sott *et al.*, 2020).

The need to digitalize agricultural activities appears essential to improve the quality and sustainability of crops (Shepherd *et al.*, 2020), to ensure better food production using few natural resources (Lezoche *et al.*, 2020), to reduce food loss and waste, and to enhance food safety by enabling product identification, tracking, and tracing throughout the overall supply chain (Akyazi *et al.*, 2020). Many of the expected advantages

of digitalization focus on higher efficiency via precision mechanization, automation, and better decision-making, as well as higher food traceability through real-time data collection.

As a result, digital transformation is playing a central role in shaping the future of the agri-food sector, embracing the challenges towards environmental, social, and economic sustainability (Abbate *et al.*, 2023).

European policies have certainly guided these choices, particularly promoting the Sustainable Development Goals (SDGs), which are part of the 2030 Agenda. They encompass concerns related to environmental and economic sustainability, as well as social issues such as hunger, poverty, job opportunities in rural areas, and knowledge transfer to new generations. Among the 17 goals, precision agriculture systems can positively impact SDG 2 related to food, SDG 6 (water), SDG 7 (energy), SDG 13 (climate change), and SDG 15 (ecosystems) (Dayioğlu and Turker, 2021).

Nevertheless, digital technologies per se do not allow the consequent accomplishment of sustainability goals at the corporate level. Indeed, assuming a socio-technical perspective, the literature stresses the need for organizations to start a profound transformation through radical changes in business models, organizational layouts, and related processes (Abbate *et al.*, 2023). Furthermore, several scholars have outlined the difficulties of embracing digital technologies and related tools, particularly those linked to farmers' resistance to technology, data analysis, and data management, as well as the need to develop new digital skills and related capabilities (Smania *et al.*, 2022). All in all, scholars have particularly focused on the technical facets of digitalization. More research is demanding about the levers through which agri-food companies can exploit the strategic potential of digitalization for achieving sustainable goals.

2.2 Innovation for sustainable value creation: the role of Digital Servitization

Business customers' expectations shifted from mere product acquisition to adopting sophisticated solutions that enable both the search for new economic opportunities and the tracking of new ways to reduce the environmental and societal impact. This means that users increasingly appreciate the inherently offered value by consuming it as a service instead of paying for the product or technology itself. Servitization, which describes the shift from a product-centric to a service-centric logic (Kowalkowski *et al.*, 2017), entails a transformation journey deeply embedded in the company's value-generating mechanisms and acts as a manifestation of the firm's business strategy (Gebauer *et al.*, 2021).

DS is based on the interplay between digitalization and servitization (Kohtamäki *et al.*, 2020; Paschou *et al.*, 2020). To approach DS, firms require both digitization and digitalization. The first one refers to the conversion of analog information into a digital format. The second one refers to the combination and recombination of digital technologies to create and harvest value in new ways through business processes automation. New technological applications unlock the potential of digital technologies such as AI and DSS to collect data, identify patterns, and make smarter business decisions (Rupeika-Apoga *et al.*, 2022). Managerial research describes

DS as a shift in service offerings towards digitalization, necessitating a reconfiguration of business models (Paschou *et al.*, 2020) towards a service orientation (Adrodegari and Saccani, 2017; Ciasullo *et al.*, 2021). Furthermore, Sjödin *et al.* (2020) define DS as "the transformation in processes, capabilities, and offerings in industrial firms and their associate ecosystems to progressively create, deliver, and capture increased service value arising from a broader range of enabling digital technologies". Thus, DS can impact both internal and external processes of firms (Coreynen *et al.*, 2017). Particularly, the back-end perspective focuses on enhancing firms' internal processes, fostering innovation, improving operational performance (Klingenberg *et al.*, 2021), and increasing decision-making transparency.

The front-end perspective emphasizes firms' external processes, fostering customer interactions and promoting closer integration with the actors' networks (Perks *et al.*, 2017; Sklyar *et al.*, 2019). Despite the clear back-end and front-end perspectives, the literature stresses the complexity that arises in handling DS all along the value chain (Tóth *et al.*, 2022). However, navigating DS along the entire value chain poses considerable complexity, necessitating coordination among intra- and inter-activities to effectively address change and adapt value propositions accordingly (Baines and Lightfoot, 2014). In this scenario, digital platforms emerge as focal drivers for addressing DS as a capability through the reconfiguration of sustainable-oriented network ecosystems in terms of both relational and structural features (Ciasullo *et al.*, 2021; Schiavone *et al.*, 2022). Such a systemic approach emphasizes the need for a progressive and comprehensive transformation of the company's ecosystems. The strategic objective is a configuration in which value is co-created through the optimization of resource usage, effective operation, and the leverage of digital technologies (Parida *et al.*, 2019). Typically, this shift can be described by the transition from product platforms to platform ecosystems built on network interactions, which represent the backbone of successful servitization strategies in sectors undergoing digital transformation (Cenamor *et al.*, 2017). A digital platform can reconfigure and reuse certain assets through modularity (Andersen *et al.*, 2022) by exploiting economies of scale and scope for reshaping the design of the product, the manufacturing process, or the distribution channel. Indeed, modularity allows a flexible configuration of several offerings using different combinations of modules for servitized products (Bask *et al.*, 2010) and an improvement in communication regarding the value proposition (Böttcher and Klingner, 2011). Moreover, digital platforms can intervene as a booster of interactions and the sharing of knowledge in the network ecosystem. Then, a digital platform may track the path for a reconfiguration of firms for better implementing DS. Consequently, it is meaningful to consider the orchestration role of a digital platform in empowering network ecosystems toward sustainable trajectories (Chen *et al.*, 2020; Schiavone *et al.*, 2022). The digital transformation brought by those platforms and the relevant digital ecosystems is thus shaped by the interaction between technologies and the people who use these technologies, as well as by innovation policies (Brunetti *et al.*, 2020).

DS represents a challenging journey, especially for SMEs, which often require collaborative partnerships to integrate new capabilities and navigate complex innovations. By analyzing the digitalization of agricultural systems, Fielke *et al.* (2020) find that the transparency of practices and informational interactions between farmers, advisors, agri-businesses, consumers, and regulators are driven by growing connectivity. When DS is successfully implemented, firms can expand their offerings through higher differentiation from rivals, increase revenues and profits, and become more resilient to changes and crises. In broader terms, considering also environmental and social aspects, DS was also found to lead companies in the manufacturing sector to increase their sustainability (Paiola *et al.*, 2021). By conducting a systematic literature review, Paschou *et al.* (2020) report several benefits of DS for society and the environment: reduction in energy consumption, decrease in environmental impact, increase in social sustainability, value delivery for the entire society, and implementation of sustainable production processes. However, this interplay remains understudied (Gebauer *et al.*, 2021), particularly concerning sustainability benefits (Paiola *et al.*, 2021) and agricultural innovation systems, despite being based on both knowledge and technological infrastructures. Particularly, Smania *et al.* (2022) discover that the DS process for original equipment manufacturers (OEMs) is driven by the implementation of precision agriculture (Agriculture 4.0) and by the changing needs of agribusinesses. Furthermore, the scholars observed: (i) an increase in productivity to compete with countries where costs are lower, and legislation is less restrictive; (ii) continuous investments in facilities to maintain efficiency; (iii) adherence to new environmental standards; and (iv) the reduction of the typical risks and uncertainties of agricultural activity.

2.3 Theoretical speculations

The analysis previously conducted highlights some important evidence in terms of antecedents and consequences of the transformation brought by the development of innovative product-service systems (PSSs) grounded on DS enabled by a platform provider.

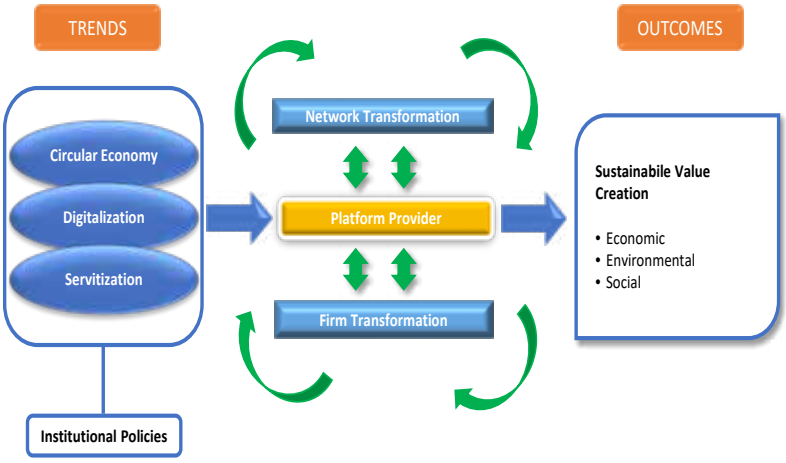
Particularly, starting from the current trends that characterize the agrifood sector, such as digital transformation, servitization, and the circular economy pushed by sustainability policies both at global and local levels (e.g., UN SDGs, EU Green Deal, New PAC, etc.), the literature emphasized the key role of partnerships. They are based on the exchange of technological innovation and knowledge as a service to support the digital transition of agribusinesses, especially SMEs (Paiola *et al.*, 2021). This helps overcome the lack of resources and competencies to reach positive outcomes in terms of economic, environmental, and societal sustainability enabled by digital innovation (Smania *et al.*, 2022).

However, this process is twofold, necessarily involving two levels of analysis (Paiola *et al.*, 2021; Parida and Wincent, 2019): (1) the transformation at a network level, where the trends can boost the interplay among partners and ecosystem orchestration; and (2) at the firm level,

where the transformation builds on the need for updating corporate resources and capabilities through the new knowledge acquired.

Based on these relationships, a conceptual framework is designed (Figure 1), which guided the empirical phase of the study.

Fig. 1: Conceptual framework of the study



Source: our elaboration

3. Methodology

3.1 Study strategy and design

To understand how a solution provider sustains sustainability gains in the agrifood ecosystem, this study adopted a sequential mixed-methods approach based on quantitative and qualitative analyses (Tashakkori and Creswell, 2007).

Firstly, to answer RQ1.1, a quantitative analysis was performed. It was based on secondary data gathered from the literature as an in-depth cost-benefit analysis. Particularly, a bibliographic analysis was carried out to identify the main operations management metrics (e.g., costs, revenues, and profits, especially connected to the phases of wine-grape growth, harvesting, and winemaking). The aim was to find out the potential improvements in terms of sustainability performance due to the adoption of innovative practices enabled by a digital PSS. Then, a comparison was performed between two types of agribusinesses: conventional firms (i.e., not supported by the services of the platform provider) and 4.0 firm (i.e., supported by precision agriculture systems).

Secondly, to answer RQ1.2, an explorative multiple case study was performed. It was useful both to capture and describe contemporary and practice-based phenomena within their natural setting, especially when the boundaries between them are blurred (Gummesson, 2017), and to

conduct the analysis according to the respondent's attitude, experiences, and behavior. The multiple case study methodology allowed researchers to deepen the phenomenon under investigation by shedding light on any differences and similarities between the cases considered. Accordingly, the reliability of the research, the replication of the analysis, and the comparability of the results can be improved (Yin, 2017). In this study, both the service provider (e.g., the focal actor) and the winery organizations were analyzed, investigating how the service platform provides smart solutions and how wineries accomplish transformational processes both at the firm and network level.

3.2 Data collection and data analysis

3.2.1 First Phase: Quantitative analysis of secondary data for the comparison between conventional and 4.0 agribusinesses

A comparison between "conventional" and "4.0" agribusinesses was performed, also pointing out the type of farming and production (e.g., organic or not). The analyzed sample was divided into different size classes: up to 2 hectares, from 2 to 20 hectares, and from 20 to 100 hectares, and the classic structure of a company income statement was considered.

Data collection was based on secondary data, considering both bibliographic studies and the focal actor's documentation. Particularly, the following studies served as the basis for the comparison: Maddalena *et al.* (2023) for the number of treatments and for costs; Caffi *et al.* (2012) and Donna *et al.* (2011) for fertilization, where the reduction in the use of fertilizers was calculated thanks to the support of satellite analysis and the use of VRT (variable rate technology) for optimizing fertilization.

The measures concerning the "conventional" farm were defined by following the study by Condifesa (2023), in which agrifood investment costs are collected from Condifesa's 10,000 members. Related findings show that the average quantity produced by the conventional vineyard and the wine yield from grapes were set at 65% accordingly.

The costs for the vinification and bottling phases were extracted from the study by Ismea (2020) and represent 35% of the total costs; moreover, average prices for non-organic and organic wines were also derived from this study.

Finally, the cost of pesticide treatments and the cost of fertilization were calculated and compared in both conventional and 4.0 farms to assess the main benefits of using smart farming systems.

3.2.2 Second Phase: Qualitative follow-up based on primary data

Both primary and secondary data were collected following a data triangulation strategy. Secondary data was collected mostly from corporate websites and internal documentation. Primary data were gathered from 10 in-depth interviews both with the service platform's founders and agronomists, as well as with the owners of wineries operating in different Italian regions that adopted services provided by the platform.

In line with the aim of the research, the unit of analysis was represented by the interplay between the service platform and the wineries to understand how the focal actor contributed to the complex transformation of wineries and their network towards sustainability gains. Data collection lasted 3 months between September 2022 and January 2023.

The authors interviewed service provider co-founders (i.e., CEO and CMO) and winery owners.

A semi-structured questionnaire was performed aimed at analyzing which services were provided by the focal actor, how these services were implemented by wineries, and which processes were renovated, thereby affecting the overall ecosystem. The interviews were audio-recorded and transcribed. Once the data was collected, it was analyzed through a content analysis, in which the authors individually examined and evaluated the interview transcripts with respect to the research's aims after sharing the research materials, methodology, and interpretive logic beforehand (Eisenhardt, 1989).

3.3 Empirical context

Elaisian is one of the first agri-tech Italian ventures, and it was founded in 2016. Its mission is "Revolution", intended as a priority in supporting the transition and renewal of local areas toward progress, competitiveness, and knowledge through innovations and new technologies. By considering business customers' needs, it provides tailor-made services and solutions, particularly precision agriculture systems. The innovative business idea has gained several awards, such as the best 100 Italian start-ups in 2020 and the best 500 FoodTech startups worldwide in 2021. The company is present in 16 worldwide countries, and more than 2,000 farming organizations are served.

4. Findings

4.1 Quantitative analysis of the empirical data from the literature

To assess the sustainability gains, findings of the comparative analysis, focus on the reductions in (i) the number of pesticide treatments and (ii) the costs for fertilization and pesticide treatments.

Particularly concerning pesticide treatments, based on the study by Maddalena *et al.* (2023) and Caffi *et al.* (2012), an average reduction of 59.5% was calculated in terms of the number of treatments and associated farm emissions and costs.

Concerning fertilization, based on the study by Donna *et al.* (2011), a 30% reduction in the use of fertilizers was calculated.

Then, the comparison between farming practices and the outputs of a winery without and with the support of 4.0 services was calculated. For pesticide treatments, an estimation of savings ranging from € 707 to € 47.320 (Table 1) and of fertilization from € 198 to € 13.860 (Table 2), respectively, for farms of 1 ha and 100 ha, was highlighted. Differences in

costs and profits correspond to a decrease of 46% in pesticide treatments and a 30% reduction in fertilization, thanks to on-field smart sensors and big data analytics. These technologies enable the precise detection of infections to prevent pathogen attacks, along with the analysis of satellite imagery by pinpointing areas requiring fertilization. Consequently, this targeted approach enhances efficiency while minimizing unnecessary impacts and soil pollution. Based on Wu *et al.* (2018), an examination of economies of scale in relation to farm size reveals significant reductions in both pesticide and fertilizer usage and costs. The study indicates that as farm size increases, there is a corresponding decrease in the use and cost of pesticides and fertilizers. Specifically, for farms both with and without agriculture 4.0, a statistical analysis demonstrates that a 1% increase in farm size corresponds to a 0.3% reduction in fertilizer use per hectare and a 0.5% reduction in pesticide use per hectare.

Tab. 1: Pesticides - Convenience in using Agriculture 4.0

Farm dimension	1 ha	2 ha	20 ha	100 ha
Pesticides without 4.0 services				
No. of treatments	26	52	494	1.300
Pesticides (€)	780	1.552	14.820	39.000
Transport and distribution (€)	520	1.040	10.400	52.000
TOTAL COST (€)	1.300	2.592	25.220	91.000
Pesticides with 4.0 services				
No. of treatments	10	21	198	520
Pesticides (€)	312	621	5.928	15.600
Transport and distribution (€)	281	562	5.616	28.080
TOTAL COST (€)	593	1.182	11.544	43.680
COST SAVINGS (€)	707	1.410	13.676	47.320

Source: our elaboration

Tab. 2: Fertilisers - Convenience in using Agriculture 4.0

Farm dimension	1 ha	2 ha	20 ha	100 ha
Fertilisers cost without 4.0 services				
Fertilisers (€)	500	997	9.700	35.000
Fertilisation (€)	160	319	3.104	11.200
TOTAL COST (€)	660	1.316	12.804	46.200
Fertilisers cost with 4.0 services				
Fertilisers (€)	350	698	6.790	24.500
Fertilisation (€)	112	223	2.173	7.840
TOTAL COST (€)	462	921	8.962	32.340
COST SAVINGS (€)	198	395	3.841	13.860

Source: our elaboration

Further insights were obtained through a comparison between conventional (non-organic) and organic winemakers. The implementation of agriculture 4.0 resulted in a quantitative reduction in pesticide treatments and fertilization by 46% and 30%, respectively, compared to conventional

farming (Table 3). In addition, the total cost savings are also positively affected by the reductions due to economies of scale deriving from the size of the farm, ranging from 5% to 9%. This leads to cost savings ranging from € 564 for farms of 1 ha to € 92.411 for farms of 100 ha. Comparing total cost savings with farm profits through the utilization of precision farming systems illustrates increased profits ranging from € 3.738 to € 409.811 for conventional farms and from € 5.854 to approximately € 621.000 for organic farms, for farms of 1 ha and 100 ha, respectively.

Tab. 3: Improved sustainability by using Agriculture 4.0

	1 ha	2 ha	20 ha	100 ha
Interventions Reduction				
Pesticide Reduction	-46%	-46%	-46%	-46%
Fertilisers Reduction	-30%	-30%	-30%	-30%
Economic of Scale Reduction in Fertilisers		0,3%	3%	30%
Economic of Scale Reduction in Pesticides		0,5%	5%	50%
Total Cost Savings				
Cost Savings (€)	564	1.892	21.917	92.411
Cost Savings (%)	5%	8%	9%	8%
Non-Organic Profits				
Higher Profits (€)	3.738	8.240	85.397	409.811
Higher Profits (%)	35%	38%	40%	36%
Organic Profits				
Higher Profits (€)	5.854	12.472	127.717	621.411
Higher Profits (%)	23%	24%	25%	24%

Source: our elaboration

In the appendix, the values related to the comparative analysis are provided (Tables 6 and 7). The section "Other Operations" describes and summarizes the main additional operations useful in wine and production. They are grouped to simplify the reading and include weeding (€210), plant replacement (€500), pruning (€2,070), uprooting plants (diseased and old) (500 €), shredding (640 €), other work (checking structures and anchorages) (150 €), harvesting (860 €), and insurance (700 €), for a total of 5,360 €.

4.2 Second Phase: Qualitative Follow-up

4.2.1 Case companies' description

All wineries are SMEs, with four of them organized as cooperatives. Table 4 shows the case companies' profiles. These wineries engage in the entire wine production process, from cultivating crops to bottling and selling the wine under their labels. They established close collaborations with Elaisian. Winery owners listed several reasons for partnering with the focal actor: "*We need to digitalize our activities to preserve the biodiversity of our terroir*", emphasizing the importance of safeguarding environmental conditions that contribute to the uniqueness of their wines; "*We need to*

better manage the riskiest danger for a winery business: vine infections", looking for preserving and valorizing natural resources through innovative systems.

Tab. 4: Case companies' profile

	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6
Location	Puglia	Campania	Campania	Tuscany	Abruzzo	Piedmont
Vineyards extension	40 ha	175 ha	100 ha	14 ha	22 ha	1 ha
Farming management	Organic	Conventional/ Biodynamic	Organic	Organic	Organic	Organic
Number of employees	10	35	3	20	5	3
Annual turnover range (€)	600.000	4Mln	35.000	1 Mln	130-140.000	15.000

Source: our elaboration

4.2.2 Digital Servitization: firms' and networking' effects

A cyber-physical system and its associated solutions, such as a cloud-based big data analytics tool, are being developed across various fields. These solutions encompass climate sensors, drones, global positioning systems (GPS), Internet of Things (IoT) devices, cloud computing, and machine learning algorithms, which collectively characterize the service platform. Its modular design allows high customization and operational adaptability, facilitating monitoring and predictive maintenance for crop management. Climate sensors allow for the control of outside temperature, humidity, solar radiation, and wind speed so that winemakers can regulate the irrigation of fields according to weather conditions. For instance, they can decide to start irrigation automatically in very cold temperatures, avoiding frost, or they can reduce the use of water when sensors perceive high humidity, which already makes fields wet. Drones can detect dry areas and address problems that traditional watering equipment may have missed.

Furthermore, they can stitch thermographic photos together over time to detect the direction of water flow and locate geographical features that may affect water dispersion, thereby preventing an ineffective and unsustainable use of water. GPS enables the coupling of real-time geospatial data, spreading accurate position information about water dispersion and dry fields. IoT is used for remote image capture and processing for the detection of insects and vine diseases and for pesticide, herbicide, and fertilizer tracking, allowing continuous and constant control and improvement of their use. The IoT is composed of interconnected sensors that collect data that is aggregated through cloud computing.

These digital solutions at the firm level allow for the collection of real-time data throughout all winery processes, which, thanks to machine learning algorithms systems are analyzed and shared through alerts in mobile apps as valuable information. Indeed, a higher awareness of the concrete possibility of facing sudden ecological and social issues and improving the effectiveness of crop management affects winemakers. As

one of the winemakers illustrated: "*Now we can map the field. For example, if you are going to fertilize a certain area or correct the soil, you can collect data in various areas where you are going to plant: soil pH, what is needed to treat the soil, and what fertilizer is missing. You can put this data into a program, and your machine, when applying fertilizer or soil correction, can apply it there via satellite*". Other winemakers affirmed: "*The quality of life of my teamwork is improved because we can now regulate water distribution and pesticide irrigation from our homes*". Moreover, thanks to GPS systems, workers' safety is reinforced because they allow to avoid human activities when adverse weather conditions arise. Accordingly, digitalization contributes to attaining service innovations both in agricultural processes and in overall value propositions, stimulating the development of innovative sustainable practices. Firstly, the large amounts of data collected and analyzed allow to better dose the water and introduce a more precise application and reduction of chemicals, tracking the path for the implementation of non-polluting pesticides, herbicides, and fertilizers. A winery owner affirmed: "*We can finally improve our complex agricultural activities by monitoring physical, chemical, and biological processes, taking into account what is best for our wineries*". Secondly, winemakers innovate the value proposition by proposing certified eco-friendly products. More in-depth, thanks to bio-organic productions, an eco-label certifies sustainable practices throughout the production cycle, from natural resource management to bottling and transportation. The winery eco-label certification enables the traceability of the product by improving its quality in terms of origin and sustainable production processes (e.g., vine protection, watering, fertilizer use, harvesting, winemaking, bottling, etc.), reinforcing its safety and reliability along the food value chain. Indeed, a winemaker affirmed: "*The digitalization of production data enables automatic transfer of data to customers, enabling them to profit from better and more reliable data*".

Winemakers' digital readiness is stimulated through interactive services that Elaisian provides through user-friendly interfaces such as machine-visual boards and mobile applications (i.e., mobile apps) that allow easy access to data. Besides, skilling and up-skilling services are provided to facilitate technical knowledge in big data analysis. As a winemaker declared: "*The building of digital skills is essential to enhance real-time communication for monitoring crop yields*". In the same direction, a winery owner stated: "*The ability to analyze data should be associated with methodological sensitiveness; data analysis can be a source of many biases. Not only should we collect information, but we should compute and interpret data in line with strategic goals to identify solutions for the development of services, products, and processes*". Given these insights, one of the Elaisian CEOs affirmed: "*We do not only provide digital solutions, but we also train our partners because they need to learn*". Also, the other Elaisian CEO declared: "*It is fundamental to allow our partners to leverage the value of digital technologies... To make data useful information, it is needed to continuously learn through various techniques, such as foresight exercises and scenario building*". Indeed, digital skills are stimulated through interactive services that Elaisian provides through user-friendly interfaces

such as machine visual boards and mobile applications (i.e., mobile apps) that allow easy access to data. Besides, skilling and up-skilling services are provided to facilitate technical knowledge in big data analysis. Particularly, the systematic computation and interpretation of data allow for the development of forecasting abilities, thereby improving overall business activities. More in-depth, the human resources involved can advance a more informed decision-making process in foreseeing pathological and physiological weather conditions.

At the network level, the digital solutions and the related services provided by the Elaisian allow winemakers to get in touch with other actors, such as suppliers of ecological raw materials, agronomists, biologists, and software engineers. Indeed, relational capabilities are fostered through the activation of synergistic interactions between winemakers and business and non-business actors. A winemaker stated: "*We collaborated with a software engineer to develop tailor-made solutions to prevent freezing temperatures, which are becoming more frequent*". Another one affirmed: "*We established new partnerships and new close relationships to share knowledge and experience in realizing sustainable solutions able not only to reduce unnecessary costs but also to generate value for our territories*". In this way, knowledge recombination within and outside winery organizations is promoted, stimulating value co-creation processes that allow to better address sustainability issues.

Tab. 5: Representative quotes

Interviewees	Representative quotes	Main Effects
Winemaker	We decided to implement new digital solutions to get a more sustainable way of doing business, but we need to be able to use them.	Managing digital solutions to shape a sustainable business model
Elaisian CEO	It is fundamental to allow our partners to leverage the value of digital technologies. To make data useful information, it is needed to continuously learn through various techniques, such as foresight exercises and scenario-building.	Providing a socio-technological infrastructure which is scalable, modular, easily accessible
Elaisian CEO	We do not only provide digital solutions, but we also train our partners, because they need to learn.	
Winemaker	The quality of life of my teamwork is improved, because we can now regulate water distribution and pesticide irrigation from our homes.	Stimulating service innovations both in business processes and in organizational processes
Winemaker	We can finally improve our complex agricultural activities, by monitoring physical, chemical, and biological processes considering what is best for our wineries.	
Winemaker	The digitalization of production data enables automatic transfer of data to customers, enabling them to profit from better and more reliable data.	
Winemaker	We collaborated with a software engineer to develop tailor-made solutions to prevent freezing temperatures which are more and more frequent.	Generating sustainable co-create activities in actors' network
Winemaker	We established new partnerships and close relationships to share knowledge and experience in realizing sustainable solutions able not only to reduce unnecessary costs but also to generate value for society.	

Source: our elaboration

5. Discussion

The two phases of the empirical analysis allowed us to explore how sustainable gains are achieved when winery businesses embrace a digital transition orchestrated by a digital service platform. By combining the evidence obtained through the primary and secondary data analysis, we detected socio-technical dynamics of change in the companies involved in the transformation operated by a service platform provider.

The comparison between conventional *versus* 4.0 farms showed that investing in precision agriculture systems generates both process efficiency and cost savings, thereby positively affecting economic and environmental value. The reduction in the use of pesticide treatments and fertilization, such as the reduction of chemical inputs in the air and the soil, increased wineries' profitability, affecting at the same time ecological sustainability. Nevertheless, a smaller reduction in the quantity and costs of pesticide treatments and fertilization is noted in the interviewed companies rather than those described in the literature. This could be explained by the average lower technological capabilities and knowledge of the analyzed organizations, which probably do not exploit the maximum benefits of smart farming services. Probably, the anomalous climatic trends of the last two years are also an explanation for this reduction.

Despite all, findings from the case studies analyzed showed a strong sustainability orientation among entrepreneurs as well as the need to innovate their business to actively resolve sustainability issues.

Then, digitalization allowed them to realize service innovation at operational and business levels by better performing agricultural processes and by proposing and communicating a new value proposition. On the one hand, agricultural processes are renewed and innovated towards bio-organic productions, where energy and natural resources are responsibly exploited. The decision-making support, based on the alerts and data provided by the platform as well as on the technical support by the agronomists, helps the users to make more effective decisions about different management issues, such as multiple pest and disease risk, the best time to start the treatment, the optimal dose of pesticide to purchase and use, the protection provided by the last treatment, the risk of abiotic stress (frost, drought or heat), the need for watering (Zhao *et al.*, 2022). On the other hand, certified eco-friendly products are designed, which improve quality and traceability. At the same time, social well-being is sustained by enhancing workers' quality of life and safety and increasing digitally specialized labor; thus, workers can perform less strenuous and more specialized tasks. Then, the value received from the platform provider sustains the optimization of back- and front-end activities, in terms of both technological and knowledge support, by creating opportunities for innovation. Indeed, the digital platform facilitated the extension of the wineries' relational system, where new collaborations and co-created partnerships were embraced, which allowed a value network transformation. Wineries' organizations embraced new value-creation modalities by engaging eco-friendly professionals (e.g., suppliers of ecological raw materials, agronomists, biologists, and software engineers), thereby going beyond the agri-food supply chain.

Consequently, new knowledge, experience, and expertise are exchanged and potentially renovated through a continuous learning process in the actors' value network. Then, a virtuous cycle of knowledge exchanges is stimulated, and a constant tension towards knowledge recombination is developed. Through the enrichment of data analytics skills in winery organizations, market intelligence activities are improved. This stimulates the activation of new modalities of interactions that boost ecosystem responsiveness in achieving sustainable innovations.

Past literature has demonstrated that standalone interventions are often not sufficient to tackle digital transformation processes from a systemic perspective (Brunetti *et al.*, 2020). This is particularly true in the case of SMEs that need partners to integrate their capabilities, considering that they operate in complex contexts characterized by transitional processes such as the agrifood industry (García-Álvarez de Perea *et al.*, 2019).

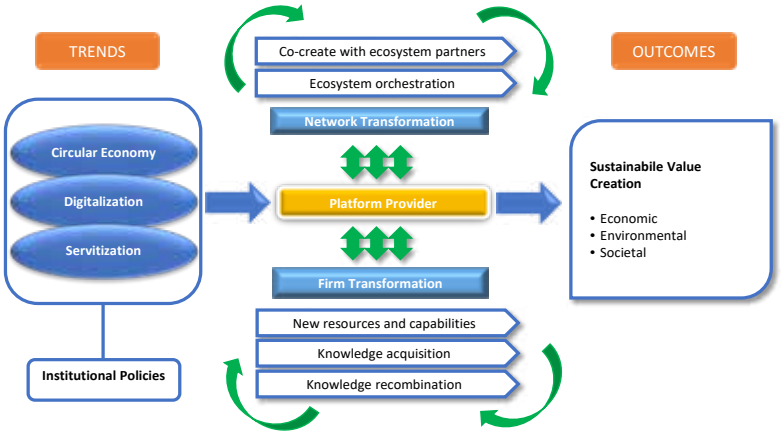
Tracking, measuring, and then identifying innovative solutions to shared problems is the key to facing common challenges and fostering sustainable outcomes in fast-changing contexts (Kamilaris *et al.*, 2017).

5.1 Revised conceptual model

The evidence obtained from the two phases of the analysis performed allowed us to update and improve the initial conceptual model (Figure 2). In the revised model, the initial two levels of analysis (Paiola *et al.*, 2021; Parida and Wincent, 2019) were confirmed and enriched by further elements: (1) at the network level, the ecosystem transformation brought about by the platform provider gives an actual boost to value co-creation among partners. This interplay, based on the exchange of information and resources among the different actors, is enabled by the ecosystem orchestration performed by the platform provider (Rapaccini *et al.*, 2023). These dynamics positively affect competitiveness at the network level and have an impact on overall sustainable value creation. At the firm level (2), this transformation allows to overcome corporate resources shortages. The continuous technical and human support received stimulates innovativeness through knowledge acquisition and new knowledge recombination, triggering innovative processes (Ayre *et al.*, 2019). This transformation represents for firms a concrete lever for achieving competitive advantage by servitizing their value propositions (e.g., organic and quality-labeled products) and the clear communication of higher sustainable performance.

Our results detect an innovation ecosystem characterized by DS and positive network effects influencing different levels of positive outcomes at the economic, environmental, social, and societal (Paiola *et al.*, 2021; Smania *et al.*, 2022).

Fig. 2: Conceptual framework updated by the empirical research



Source: our elaboration

6. Theoretical and managerial implications

The study investigates how sustainability is enhanced in farming businesses through the involvement of a digital service platform. The study has both theoretical and managerial implications.

Theoretically, by assuming a socio-technical perspective, the research contributes to advancing the scant managerial literature focused on digital transformation in the agricultural setting. Indeed, it provides an empirically informed conceptual framework that illustrates the enabling effects that shape a sustainability-oriented ecosystem. The close collaboration between the digital service provider and the analyzed wineries encompasses technological advancement, hard and soft skill development, and actors' network interactions, creating and nurturing a more sustainable value-driven ecosystem.

From a managerial viewpoint, this study helps managers understand how to effectively combine data management strategies and human resources management to turn meaningless data into valuable knowledge. This, in turn, promotes the alignment of complex innovation processes that influence the sustainability of the company and potentially other connected stakeholders.

In addition, evidence from the case studies can inform both practitioners and policymakers about the best practices and process innovation activities that can increase shared value creation in the agrifood ecosystem.

7. Conclusion

The results obtained through the mixed-method design of this study allowed a direct comparison between secondary and primary data. In the first case, data have been standardized for "typical companies" and represent

a guideline for comparative analyses of agrifood companies' operations management performance in the wine-growing business. Primary data from case studies are more representative of the current Italian scenario of winery companies implementing smart farming services.

Particularly in the investigated context, significant benefits in terms of sustainable outcomes were observed for companies implementing smart farming services, which are, however, supported by the continuous training offered by the platform provider. In this way, companies can contribute positively to both society and the natural environment. Indeed, they improve the sustainability of production processes by innovating with highly efficient and cost-effective systems, both in terms of business and collective well-being, thanks to the observed network effects. The synergic interplay with the service provider allows wineries to exploit the platform value by acquiring and exchanging knowledge in their value network towards an improvement of sustainable outcomes both at firm and network levels.

As per the limitations of the study, our evidence is mainly based on the analysis of Italian wineries enhanced by a specific innovative platform provider. The limited number of collected cases discourages a consistent generalization of the results achieved so far, which will have to be confirmed by further investigation. Particularly, more empirical evidence is needed to generalize the observed technology-driven transformation dynamics and outcomes. Moreover, further research could focus on other agrifood industries or niches in different geographical areas, as well as different types of platform providers and related business models, in which different sustainable benefits could be achieved. At the same time, the collection of quantitative primary data would allow future researchers in this field to confirm the overall results presented above. The experience of agribusinesses from different countries and crops may also be beneficial to add further elements to the relationships included in the present conceptual framework, which is highly dynamic for its nature.

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sinergie
italian journal of management
Vol. 42, Issue 1, 2024

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Appendix

Tab. 6: Profit and loss account - Without 4.0 services

FARM NOT USING 4.0 SERVICES	1 ha	2 ha	20 ha	100 ha
COSTS				
Fertilisers	500,00 €	997,00 €	9.700,00 €	35.000,00 €
Fertilisation	160,00 €	319,04 €	3.104,00 €	11.200,00 €
FERTILISERS TOTAL COST	660,00 €	1.316,04 €	12.804,00 €	46.200,00 €
No. of pesticide treatments	26	52	494	1300
Pesticides	780,00 €	1.552,20 €	14.820,00 €	39.000,00 €
Pesticide transport and distribution	520,00 €	1.040,00 €	10.400,00 €	52.000,00 €
PESTICIDES TOTAL COST	1.300,00 €	2.592,20 €	25.220,00 €	91.000,00 €
OTHER OPERATIONS TOTAL COST	5.630,00 €	11.260,00 €	112.600,00 €	563.000,00 €
Total cost Vinification and bottling	4.086,00 €	8.172,00 €	81.720,00 €	408.600,00 €
TOTAL COST WITHOUT 4.0 SERVICES	11.676,00 €	23.340,24 €	232.344,00 €	1.108.800,00 €
	11.676,00 €	23.340,24 €	232.344,00 €	1.108.800,00 €
INCOME				
Grape production q/ha	100	200	2000	10000
Wine production l/ha	6500	13000	130000	650000
Price €/l - Non-Organic	3,45	3,45	3,45	3,45
Price €/l - Organic	5,75	5,75	5,75	5,75
TOTAL INCOME NON-ORGANIC WITHOUT 4.0 SERVICES	22.425,00 €	44.850,00 €	448.500,00 €	2.242.500,00 €
TOTAL INCOME ORGANIC WITHOUT 4.0 SERVICES	37.375,00 €	74.750,00 €	747.500,00 €	3.737.500,00 €
PROFITS NON-ORGANIC WITHOUT 4.0 SERVICES	10.749,00 €	21.509,76 €	216.156,00 €	1.133.700,00 €
PROFITS ORGANIC WITHOUT 4.0 SERVICES	25.699,00 €	51.409,76 €	515.156,00 €	2.628.700,00 €

Tab. 7: Profit and loss account - With 4.0 services

FARM NOT USING 4.0 SERVICES	1 ha	2 ha	20 ha	100 ha
COSTS				
Fertilisers	350,00 €	697,90 €	6.790,00 €	24.500,00 €
Fertilisation	112,00 €	223,33 €	2.172,80 €	7.840,00 €
FERTILISERS TOTAL COST	462,00 €	921,23 €	8.962,80 €	32.340,00 €
No. of pesticide treatments	10,4	21	198	520
Pesticides	312,00 €	620,88 €	5.928,00 €	15.600,00 €
Pesticide transport and distribution	280,80 €	561,60 €	5.616,00 €	28.080,00 €
PESTICIDES TOTAL COST	592,80 €	1.182,48 €	11.544,00 €	43.680,00 €
OTHER OPERATIONS TOTAL COST	5.630,00 €	11.260,00 €	112.600,00 €	563.000,00 €
Total cost Vinification and bottling	3.927,00 €	7.585,00 €	74.620,00 €	369.869,00 €
SMART FARMING SERVICES TOTAL COST	500,00 €	500,00 €	2.700,00 €	7.500,00 €
TOTAL COST WITh 4.0 SERVICES	11.111,80 €	21.448,71 €	210.426,80 €	1.016.389,00 €
INCOME				
Grape production q/ha	106	212	2120	10600
Wine production l/ha	7420	14840	148400	742000
Price €/l - Non-Organic	3,45	3,45	3,45	3,45
Price €/l - Organic	5,75	5,75	5,75	5,75
TOTAL INCOME NON-ORGANIC WITHOUT 4.0 SERVICES	25.599,00 €	51.198,00 €	511.980,00 €	2.559.900,00 €
TOTAL INCOME ORGANIC WITHOUT 4.0 SERVICES	42.665,00 €	85.330,00 €	853.300,00 €	4.266.500,00 €
PROFITS NON-ORGANIC WITHOUT 4.0 SERVICES	14.487,20 €	29.749,29 €	301.553,20 €	1.543.511,00 €
PROFITS ORGANIC WITHOUT 4.0 SERVICES	31.553,20 €	63.881,29 €	642.873,20 €	3.250.111,00 €

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italian journal of management

ISSN print 0393-5108
ISSN online 2785-549X
DOI 10.7433/s123.2024.03
pp. 45-69

Business model innovation and ambidexterity in Industry 4.0

Received
17th March 2023
Revised
22th May 2023
Accepted
20th March 2024

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Abstract

Framing of the research. *The Fourth Industrial Revolution (I4.0) is dramatically affecting firms' strategies, disrupting their business models. In particular, a bunch of digital technologies like IoT (Internet of Things), cloud platforms, big data, artificial intelligence and data analysis are offering firms the possibility to manage products functions, remotely and globally, kick-starting the design of innovative business models.*

Purpose of the paper. *Using studies that have analyzed the link between business model innovation and ambidexterity as theoretical background, the aim of the paper is to investigate how incumbent BtoB manufacturing firms develop an I4.0 disrupting business model by addressing the related duality between exploration and exploitation (ambidexterity).*

Methodology*. The paper fulfils its purposes by the means of a qualitative investigation, discussing empirical evidence coming from a cross-case analysis of 25 Italian SMEs and medium-large enterprises, selected crossing secondary data and indications coming from a specific panel of ten industry experts.*

Results*. The impact of I4.0 technologies on firms' business models depend heavily on the access to user-firms' data. 21 firms are involved in non-disruptive modifications of the business model; 4 firms are conducting more sophisticated experimentations in result-oriented product-service systems. These firms, that we have named "challengers", are in a privileged position in order to unleash the potential of I4.0, introducing advanced services directly related to the customers' needs. All these challengers adopt a particular form of contextual ambidexterity in which the exploration activities involve specifically selected (key) customers.*

Practical implications*. Managers need to understand which are the pace and extent of change for the various components of the corporate business model to innovate during each specific step of transition towards I4.0 technologies.*

Research limitations. *The main limitation of the study is because the investigated companies were going through a transition phase: therefore, we can't tell what the outcome of this evolutionary journey will be, and if it will be the same for every firm.*

Originality of the paper*. The paper proposes an original framing that contributes theoretically to the literature interfacing business model innovation and ambidexterity management. In particular, the study enhances our knowledge about contextual ambidexterity, a concept as rich in charm as poorly explored in practice.*

Key words: *business model innovation; ambidexterity; I4.0; BtoB manufacturing firms; Italy*

1. Introduction

The Fourth Industrial Revolution (Industry 4.0, I4.0) is dramatically affecting firms' behaviors and strategies, transforming products design, manufacture, operations and services. This disruption is in particular linked to a series of digital technologies within the I4.0 framework that will dramatically change the way firms operate in their markets (Meindl *et al.*, 2021). Among I4.0 technologies, a set of outward-oriented, front-end set of technological streams - IoT (Internet of Things), cloud platforms, big data, artificial intelligence and data analysis - are transforming business markets landscapes, offering firms the possibility to monitor, optimize and automatize product's functions, remotely and globally (Paiola and Gebauer, 2020). These technologies are at the core of a radical transformation of manufacturing, changing firms' business models with the expansion of service innovation opportunities.

The interplay of sensors and the development of the internet is central to I4.0: IoT enables data gathering from smart and connected devices, providing firms with strategic information input (Laudien and Daxböck, 2016; Santos *et al.*, 2017). IoT is therefore playing a critical role within I4.0 technologies (Arnold *et al.*, 2016). In particular, in this paper we refer to the IoT applied in industry, or the Industrial IoT (IIoT), where software-embedded intelligence is integrated in industrial devices, products and systems (Paschou *et al.*, 2020; Rymaszewska *et al.*, 2017).

By enabling communications with and among things, IoT has opened the possibility to gather fine-grained real-time data coming from relatively inexpensive sensors and actuators embedded in objects and devices from all over the world. This potentially enormous flow of data (big data) poses unprecedented challenges in collection, storage, processing and analysis (Santos *et al.*, 2017). This challenge involves also industrial services (Gebauer *et al.*, 2020), since data can be leveraged in order to enhance products and design innovative product-service systems (Belvedere *et al.*, 2013), optimize customer segmentation, positioning and pricing strategies and modify business models' component configurations over time (Santos *et al.*, 2017).

Overall, new and disruptive business models are emerging in the I4.0 landscape, posing big challenges to entire industries (Stock and Seliger, 2016). The aim of this paper is to investigate this phenomenon from the point of view of incumbent BtoB manufacturing firms, whose traditional strategies are not suitable for dealing with the ongoing digital revolution (Paiola and Gebauer *et al.*, 2020; Laudien and Daxböck, 2016; Müller *et al.*, 2018). Specifically, using studies that have analyzed the link between business model innovation and ambidexterity as theoretical background, our research question is: how do incumbent BtoB manufacturing firms engaged in the digital transition develop a disrupting business model by addressing the related duality between exploration and exploitation, that is, the ambidexterity dilemma? This question has not yet been addressed by empirical research, as indicated by the very recent review of the literature on ambidexterity and disruptive business model innovation conducted by Stoiber *et al.* (2023). The empirical section involves 25 Italian BtoB

manufacturing firms, whose strategic shifts related to I4.0 technologies are described and analyzed in relation to business model innovation.

The paper proposes an original framing that contributes to the literature interfacing business model innovation and ambidexterity management: capitalizing on previous studies and on the empirical evidence, the paper investigates a so far overlooked topic, related to the circumstance in which incumbent firms in given industries disruptively innovate their own current business models. Moreover, findings allow us to explore the circumstances under which contextual ambidexterity may represent a superior strategy and a viable perspective for firms facing disruptive technological change as is the case in the I4.0 scenario.

2. Theoretical background

2.1 The impact of I4.0 on business models: new services and revenue models

Despite the noteworthy role of technology in I4.0, scholars maintain that it is only part of the picture (Arnold *et al.*, 2016). In fact, firms have to work hard on their business models in order to exploit technological opportunities and avoid disruption, since "a mediocre technology pursued within a great business model may be more valuable that a great technology exploited via a mediocre business model" (Chesbrough, 2010, p. 355).

Even if a thorough review of business model literature is far beyond the aim of this paper, some further considerations regarding the concept of business model may be useful in order to properly introduce the importance of business model innovation and to better understand the scope of the ongoing transformation. Essentially, a business model summarizes the architecture and logic of a business (Baden-Fuller and Morgan, 2010): either explicitly or implicitly, whenever a firm is established, it employs a particular model that describes "the design or architecture of the value creation, delivery, and capture mechanisms it employs" (Teece, 2010, p. 172), that is fundamental functions in the strategic life of a firm.

Therefore, business model innovation is a process through which firms realize changes in the activities and functions within their business models and explore new architectural designs: it consists in exploring new possibilities related to value proposition definition, value creation, distribution and capture for customers, suppliers and partners (Casadesus-Masanell and Zhu, 2013).

Given this, an important aspect that literature has dealt with - that is connected to the definition itself of business model innovation - is related to the magnitude of the change, or the circumstances under which we can define that a modification in the business model is an innovation (Loebbecke and Picot, 2015). In fact, modifications in the business models can pose serious challenges to firms, impacting heavily on their efficiency, complementarities, lock-in, novelty and the linkages among them (Amit and Zott, 2001). At this regard, literature on business model innovation presents two conflicting approaches, i.e., incremental versus radical (disruptive) innovation (Wahyomo, 2018).

The circumstance is particularly important here, since it refers directly to the question whether I4.0 calls for an adjustment or a radical change in the business model. At this regard, literature has highlighted some of the main consequences of I4.0 technologies on firms' strategies (Ritter and Pedersen, 2020): for instance, Laudien and Daxböck (2016) describe how a "full utilization of IIoT" requires a radical innovation of the firms' business model. Innovative firms are now encouraged to leverage on services in order to create entirely new business models, finally migrating from product-centric approaches to service-oriented ones (Coreynen *et al.*, 2017). In fact, counting on hundreds or thousands smart and connected devices installed at the premises of final-user firms is something that can change the rules of the competition, making space for brand new data-based service-oriented business models (Raddats *et al.*, 2022).

Consequently, I4.0 technologies affect the design and development of the offering, in the direction of a dramatic expansion of service innovation opportunities, increasing the relevance of the transition of manufacturing firms toward service-based strategies. The connection between I4.0 technologies and service development is so firm that, recently, a growing research stream has begun to study technology as an enabler for servitization, triggering "digital servitization" as a specific research stream (Paschou *et al.*, 2020).

Thus, thanks to technologies, manufacturing firms can unlock the supply of product-service systems (PSSs) (Pirola *et al.*, 2020): firms' value propositions shift gradually away from pure products toward pure services, in the form of use-oriented and result-oriented offerings, gradually changing the focus towards advanced forms of market relations in which a solution is being purchased and paid for. While a product-oriented PSS is perfectly fit for the manufacturing firm's classical repertoire, use-oriented and result-oriented ones are more distant from traditional business models adopted and call for major redefinitions of the firms' business models.

In fact, I4.0 is both able to "boost" traditional industrial services (like maintenance), and to be the starting point of a potential disruption of traditional BtoB business models. In particular, IoT-based use-oriented and result-oriented PSSs imply a radical shift in the fundamental revenue models of the firms, introducing usage-based, performance-based and value-based revenue models (Adrodegari and Saccani, 2017). Capital equipment manufacturers that are used to achieve profitability from conventional services such as spare parts are therefore beginning to change their value propositions toward PSSs (Hypko *et al.*, 2010; Kohtamaki *et al.*, 2021), and to look to those new revenue models (Rymaszewskaa *et al.*, 2017). This is changing the mechanisms of revenue generation (along with costing structures, risk assessment and reciprocal liabilities among partners) from a transactional perspective to a relationship-based one (Gaiardelli *et al.*, 2014).

If we consider that "the more challenging the revenue architecture, the greater the changes likely to be required to traditional business models" (Teece, 2010, p. 186), we can assume that those changes will not be trivial. A particularly problematic scenario is present whether a relevant change in the business model core elements is expected, and when furthermore the

changes might lead the existing business models to become obsolete and uncompetitive, putting organizational structures and culture at stake (Bock *et al.*, 2012). Those challenging problems will be the object of the following section, that deals with business model innovation crucial questions that are relevant for our research.

2.2 Business model innovation and ambidexterity: a critical review

The literature on business model innovation has shed light on important issues (Spieth *et al.*, 2014; Wahyono, 2018). But when it comes to considering the crucial question of how an incumbent firm in a given sector disruptively innovates its own business model, we realize there is still a sizable area to explore (Paiola *et al.*, 2022). The perspective of ambidexterity, in the sense of exploration-exploitation à la March (1991), clearly seems to be the most appropriate for framing cases of business model innovation of disruptive type because developing a radically new business model demands an exploratory process that is particularly onerous from the point of view of the resources required. But the link between ambidexterity and business model innovation has only recently begun to attract scholarly attention (Khanagha *et al.*, 2014; Markides, 2013; Ricciardi *et al.*, 2016; Sosna *et al.*, 2010).

In this interfacing literature, the contribution from Markides (2013) serves as a useful starting point in order to arrive at our research question, which is the previous one specified in the emerging scenario of the I4.0. He claims that the simultaneous management of dualities such as exploration and exploitation, efficiency and flexibility, or low cost and differentiation, has been framed as an ambidexterity issue. From this starting point, the problem the author wishes to analyze is how a firm can compete with two conflicting business models simultaneously, that is one additional type of duality a firm may face. More precisely, in certain circumstances firms must develop a new and disruptive business model, that it is conflicting with the extant one. For this ambidexterity challenge, Markides identifies three possible solutions: 1) spatial separation, 2) temporal separation, or 3) contextual ambidexterity.

In the first, two business models are physically separated into two distinct organizations, or organizational units within the same organization (O'Reilly and Tushman, 2004). Instead, the temporal separation strategy means that a firm starts out by putting the new (and conflicting) business model "in a separate unit but reintegrate it in the main business over time (i.e., phased integration strategy)" (Markides, 2013, p. 315). The discriminatory variable between spatial separation and phased integration is the (perceived) strategic relatedness between the market for the established business model and the market for the new one. If this relatedness is weak, then firms will opt for separation; if it is strong, they will choose phased integration, or a simpler and manageable transition to duality (Visnijc *et al.*, 2021). In the latter case, a firm aims to exploit synergies between the new market and the existing business, but prefers to "separate for a period of time and then slowly merge the two concepts so as to minimize the disruption from the conflicts" (Markides, 2013, p. 25).

While using the former two solutions the conflicts between two business models are solved by managing them separately (in the early stages, at least), the third solution (contextual ambidexterity) involves managing the business models simultaneously. Following Gibson and Birkinshaw (2004, p. 210), this kind of ambidexterity is achieved "by building a set of processes or systems that enable and encourage individuals to make their own judgments about how to divide their time between conflicting demands for alignment and adaptability", i.e., between exploitation and exploration. In this case, every individual working in a given organizational context is ambidextrous (Birkinshaw and Gibson, 2004). However, in Markides (2013) and other authors (Hu and Chen, 2016; Lavie *et al.*, 2010; Spoiler *et al.*, 2023; Winterhalter *et al.*, 2016), the meaning of contextual ambidexterity is broadened, providing a multifaceted construct that indicates more than one way to handle two business models within the same organizational context. Accordingly, contextual ambidexterity includes those cases where some employees manage the relationships with demanding clients whose complex needs require a superior exploration investment (Bednarek *et al.*, 2016; Im and Rai, 2008). However, as Markides (2013, p. 317) points out, it is by no means easy to create an organizational context suitable to manage two conflicting business models simultaneously: "On one hand, it [the firm] has to create enough distance between the two business models that they don't suffocate each other; on the other, it has to keep them close enough to exploit synergies between the two".

The ambidexterity considered in Markides's typology concerns the duality between conflicting business models. But it can also be interpreted in the sense of an ambidexterity revolving around the classic dichotomy of March's exploration-exploitation (1991), bearing in mind that research on ambidexterity seems to have converged mainly on this type of duality (Birkinshaw and Gupta, 2013; Junni *et al.*, 2013; Stadler *et al.*, 2014). However, we simply need to acknowledge, according to some authors (Bröring and Herzog, 2008; Gerdoçi *et al.*, 2018; Sun and Lo, 2014), that exploration and exploitation may hardly be completely separated. Therefore, in the cases of a dual business model considered by Markides, the new business model is distinctive for its strong focus on the exploratory activity, whereas exploitation amply prevails in the extant business model. In the case of contextual ambidexterity, the old and new business models - which differ considerably in their balance of exploration and exploitation, and (partly for this reason) are also in conflict with one another to some degree - must coexist and interact in the context of the same organizational structure, posing contrasting demands to management (Andriopoulos and Lewis, 2009). On the other hand, spatial separation or temporal separation of the two business models are variants of structural ambidexterity, in the sense of the ambidexterity that can be achieved by creating dual structures (Altuna *et al.*, 2015; Bröring and Herzog, 2008; Gibson and Birkinshaw, 2004; Raisch and Birkinshaw, 2008).

Having clarified this point, the contribution from Markides (2013) serves as an important reference when dealing with the topic of disruptive business model innovations. His concept of business model duality can be further refined by explicitly considering the presence of a strategic

innovator in the market. In the paper that inspired the first two solutions envisioned in Markides (2013), Markides and Charitou (2004) wrote that the problem of how a firm can adopt two different business models in the same market "has become particularly pressing for an increasing number of established companies that have recently come under attack from 'strategic innovators' - companies that attack the established players by using radically different business models" (p. 22). But unfortunately, this is not the problem that Nestlé (one of the exampled mentioned by the authors) faced when introducing Nespresso to the market. In this case (as in others), Nestlé was the strategic innovator.

Therefore, distinguishing the situations in which there is a strategic innovator serving as a reference for the focal firm from those where the latter develops its own disruptive business model, is of uttermost importance for our discourse. To do that, we can think in terms of the investments in exploration, i.e. of the investments in knowledge needed to embark on the exploratory activity. The level of such investments correlates with the degree of uncertainty inherent in the exploratory process, and it is lower if there is a strategic innovator, and higher without it. In the former case, there is indeed a sort of "template" - to borrow a concept used in studies on the replication of organizational routines (Winter and Szulanski, 2001) - that the follower can use to speed up the process of exploration learning, and reduce the related costs and uncertainties. For instance, it may recruit some of the strategic innovator's key employees, who have experience of the new business model (Wezel *et al.*, 2006). Figure 1 shows the differences in the two above-described types of disruptive business model innovation (I and II), together with the spatial and temporal separation strategies that may be feasible in both situations, but under different circumstances.

The double arrow connecting the existing business model with the new one in Figure 1 indicates that the two business models are destined to coexist within the scope of the firm, even if they demand a temporary or permanent separation on the organizational level. This prerogative is shared by all the cases of structural ambidexterity contemplated in Markides (2013)'s framework: online trading systems; internet banking and internet brokerage; budget, no-frills flying; and others (Markides and Charitou, 2004). We frequently find such cases in the literature on business model *Innovation,* which has flourished in the last 15 years largely thanks to advances in ICT, and to the fact that many e-businesses are based on new business models (Amit and Zott, 2012; Casadesus-Masanell and Ricart, 2010; Shafer *et al.*, 2005). The adoption of a cloud business model by Telco, studied by Khanagha *et al.* (2014), also belongs to this typology, as an example of temporal separation. More in general, spatial or temporal separations are typical of strategies to develop a new market segment, as illustrated by the case of Nestlé. Consequently, the main source of conflict between the two business models derives from a cannibalization between the corresponding market segments (Markides and Charitou, 2004; Velu and Stiles, 2013).

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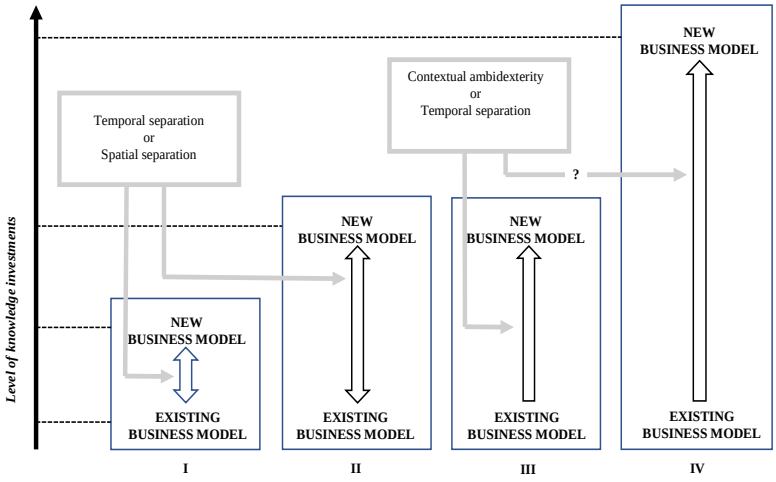
italian journal of management
Vol. 42, Issue 1, 2024

Fig. 1: Disruptive business-model innovations: a typology



Source: our elaboration

But what happens when an existing business model has to be switched to a new one (type III in Figure 1)? There are numerous anecdotal accounts of such a situation, but - to the best of our knowledge - only Sosna *et al.* (2010) have proposed an interpretation through the dual lens of business model innovation and exploration-exploitation ambidexterity. Their in-depth study concerned a Spanish dietary products company that was converted from a foodstuffs wholesaler into a franchisor managing the international retailing network Naturhouse. The strategy adopted by the firm to complete its business model "metamorphosis" (as the authors named it) involved what Markides (2013) called a temporal separation. However, the final solution didn't entail an integration of the two business models - which remained distinct (as in type II) - but a dissolution of the old model, which was replaced by the new one (type III). Actually, even contextual ambidexterity is a theoretical option in case of type III, whereas spatial separation - by definition - makes no sense in such cases.

At this point, we can set the stage for our study, which certainly differs from the above-mentioned one (type III) in that the exploratory process entails a higher level of investments in knowledge. This is because I4.0 is an even more broadly open scenario, rich in opportunities, but also burdened with uncertainties. In particular, exploring opportunities in I4.0 demands the ability to master different knowledge domains and be able to combine them together. Facing such a level of exploration breadth[1] clearly means raising exploration investments (type IV in Figure 1). But then, in the current phase at least, firms that advance on the I4.0 frontier should all be seen as pioneers, i.e., they cannot draw on successful prior experiences of strategic innovators that they might observe and imitate (as

[1] The concept of exploration breadth draws on that of knowledge breadth, which refers to the range of fields over which a firm has knowledge (Prabhu *et al.*, 2005).

in III). Moreover, their goal may be not to juxtapose two business models, but to transition from one to another (as in III). Finally, the choice of which strategy to adopt - temporal separation *versus* contextual ambidexterity - clearly remains an open question, that our study attempts to answer. At the same time, bearing in mind the abovementioned broad definition of contextual ambidexterity, we also look into the solution adopted by each firm to manage its metamorphosis.

3. Methodology and empirical setting

As I4.0 is still an emerging and puzzling phenomenon, we designed an explorative qualitative investigation, implementing a cross-analysis of different companies, coherently with well-known specific literature on qualitative research and collective case-study (Eisenhardt, 1989; Yin, 1994).

Consistently, instead of aiming at building a statistically representative sample we preferred to focus on diversity, designing a setting able to describe the different situations and challenges facing firms in the I4.0 scenario described above (Miles and Huberman, 1994). In a preliminary investigation phase, using a semi-structured interview template, we interviewed 10 industry experts selected on the base of their specialization in the field and their expertise using secondary data, personal and professional contacts.

Their indications and suggestions have been critical in the subsequent phase of selecting the sampled firms. We constructed a preliminary list of firms as coming from the experts' suggestions and started to contact top managers belonging to the different companies, targeting both top managers (CEOs, and GMs) and specific function managers presumably directly involved in the transformation elicited by I4.0 (like CTOs, CIOs, etc.). Once the contact was established, a first personal phone call by the researchers was managed in order to explain the nature and aims of the research, to assess the firm's willingness to participate in the investigation and identify which managers/professionals was specifically to be involved in the interviews. Between the beginning of 2017 and mid-2018, we collected data coming from several in-depth face-to-face semi-structured interviews with firms' key-informants and top managers in charge of technological or specifically IoT-related activities, like Chief Executive Officers, General Managers, and others.

Tab. 1: Empirical cases, firms' characteristics and interviews outline

Company	Industry	Rev. (mio)	Emp.	Value system*	Sales model°	Product type (prevalent)	Digital technologies^	Interviews, roles, total duration§
1	Professional equipment	3	8	OEM	Indirect	Standard	IOT	1, SM, 2h
2	Machine tools	8	26	OEM	Direct	Custom	IOT	2, CEO, 2,5h
3	Professional equipment	6	30	OEM	Indirect	Standard	IOT, Cloud	2, CEO, CTO 3h
4	Mechanical components	8	34	OES	Indirect	Standard	IOT, Cloud, DA	2, CEO, 2,5h
5	Packaging machines	20	84	OEM	Direct	Custom	IOT	2, CEO, CMM, 2h
6	Packaging machines	50	120	OEM	Direct	Custom	IOT, Cloud, DA	2, BD, 3,5h
7	Inspection machines	37	143	OEM	Direct	Custom	IOT	1, CTO, COO, 2h
8	Professional equipment	105	150	OEM	Indirect	Standard	IOT, cloud	2, CEO, 2,5h
9	Heating control systems	48	195	OES	Indirect	Standard	IOT, Cloud	3, CTO, CMO, 4h
10	Heating devices	61	233	OEM	Indirect	Standard	IOT, Cloud, DA	3, CEO, 4h
11	Food machines	150	250	OEM	Indirect	Standard	IOT, Cloud, DA	3, SM, CTO, 5h
12	Home automation	130	410	OEM	Indirect	Standard	IOT, Cloud	2, CTO, 2h
13	Diagnosis machinery	90	458	OEM	Indirect	Custom (modular)	IOT, Cloud, DA	1, CMM, CTO, 2h
14	Heating control systems	166	602	OES	Indirect	Standard	IOT, Cloud	4, CTO, CIO, 5h
15	Machine tools and plants	202	652	OEM	Direct	Custom	IOT, Cloud, DA	3, CTO, CHRO, 5h
16	Retail equipment	240	697	OEM	Direct	Standard (modular)	IOT, DA	2, CTO, 3h
17	Off-road automation	157	743	OES	Indirect	Standard	IOT, Cloud	4, CEO, CTO, 4h
18	Water management devices	278	761	OEM	Indirect	Standard	IOT, Cloud	1, SM, CTO, 5h
19	Heating components	276	801	OES	Indirect	Standard	IOT, Cloud	3, CEO, CTO, 3h
20	Heating equipment	235	820	OES	Indirect	Custom (modular)	IOT, Cloud	3, CEO, SM, CTO, 4,5h
21	Coffee and coffee machines	381	842	OEM	Indirect	Standard	IOT, Cloud, DA	2, CTO, 4h
22	Retail equipment	225	975	OEM	Direct	Standard (modular)	IOT, Cloud, DA	1, CMM, 2h
23	Packaging machines	219	1005	OEM	Direct	Custom	IOT, Cloud, DA	3, GM, 5h
24	Home automation	211	1058	OEM	Indirect	Standard	IOT, Cloud	4, CMM, 4h
25	Packaging machines	239	1263	OEM	Direct	Custom	IOT	1, CTO, 1,5h

* OES: Original Equipment Supplier, OEM: Original Equipment Manufacturer.

° Direct: prevalent direct relations with customers; Indirect: prevalent use of distribution channels.

^ DA: Data Analysis.

§ BD: Business Developer; CHRO: Chief Human Resources Officer; CIO: Chief Information Officer; CMO: Chief Marketing Officer; COO: Chief Operations Officer; CTO: Chief Technology Officer; GM: General Manager; SM: Service Manager.

Source: our elaboration

In many cases, two or more people have been involved in the interviews, for a total duration of approximately 77 hours. The aim of the field research was to get detailed information on the type of technologies used by the firms, the current and potential use of those technologies and the resulting changes in the business model. Table 1 portraits an outline of the sample: the total number of interview sessions, roles of the interviewees, total duration of the interviews.

Interviews were registered, transcribed, and coded to be able to better understand differences and similarities among companies. Follow-up meetings and calls have been arranged to deal with any unclear topic and avoid any misinterpretation. Main results of the investigation have been shared with interviewees in the form of an accurate presentation of the findings to have a first and direct feedback regarding the accuracy of the data.

As Table 1 shows, the empirical investigation has involved 25 Italian firms in various degrees involved in digital transformation processes. All

the firms are located in the North of Italy (in particular: Emilia Romagna, Friuli, Lombardy, Veneto), a geographical location that - in terms of manufacturing production - has a long and acknowledged tradition and a world-class standing, being the most advanced industrial regional system in the country and one of the most relevant in UE (De Marchi and Grandinetti, 2017).

The sampled firms cover a large array of industrial specializations that are heavily involved in technological evolutions related to I4.0, like the production and manufacturing of machine tools and plants, mechanical components, packaging machines, food processing machines, inspection and diagnosis machines, water management devices, professional cooking equipment, retail equipment, heating control systems and devices, off-road automation devices, home automation. Therefore, the empirical sample was set to provide sketches of strategies, problems and challenges of different firms in different contexts, in order to facilitate the emersion of a differentiated portfolio of technology utilization and business model innovations.

In fact, selected firms have different value chain positions (19 OEMs and 6 OESs) and sales models (9 firms sell prevalently directly to their final-user firms, while 16 have a mainly indirect access to the customers). One firm is below 20 employees and qualifies as very small, whether a core group of 11 enterprises are SMEs, employing a range of 20-500 people. A final group of 13 firms are medium- to large-enterprises, with a total number of employees above 500. In line with Laudien and Daxböck (2016), no large multinational corporation has been included in the investigation, and only two firms in the sample have more than 1.000 employees.

Firms' competitive strategies are frequently characterized by segment or niche focalization, with a consequent specialization of resources, capabilities, products and services: 10 firms prevalently customize their products and solutions on customer's needs, while standard products are mainly produced in low to medium batch sizes. Very often, firms are leaders in the respective niche / industry, testifying for a tradition of good managerial capabilities and successful strategic alignment with the environment. Nonetheless, they are looking at the present technological transformation with great attention and caution, with the consciousness that the change could be both an opportunity and a threat.

On the whole, the sampled firms are trying to figure out how to use technology in order to modify their value propositions, conveying new services and nurturing new relations. Every firm has invested in technologies able to make its products smart and connected (i.e., IoT) but not in every case the digitalization is complete: only 8 firms out of 25 have deployed solutions that involve all the technologies we deem critical for I4.0 (IoT, Cloud platforms, Data analysis) and have started to gather and analyse data coming from the installed base (in various degrees and with different time spans).

While every company has a clear idea of what I4.0 technologies can do for basic services that are traditionally offered by BtoB manufacturing firms (such as maintenance and assistance), on the other hand, radical changes have been projected, analyzed and acted in very few cases. The

introduction or testing of disruptive value propositions and business models is consequently very uncommon. In particular, as we will see in the proceeding of the work, the circumstance whether the firm has a direct contact with the final user is critical in shaping its strategy.

4. Value proposition shifts and business model changes

Table 2 represents basic features of business model changes caused by I4.0 in the sampled firms, especially as regards the change of the value proposition toward advanced services. All the firms are exploring the possible uses of I4.0 for sustaining their value propositions, aiming at enhancing services already provided or introduce new ones, as in the cases of maintenance ticketing, warranty management or Remote Condition Monitoring. If, on the one hand, those service-oriented uses of I4.0 may be technically challenging, on the other they remain within the domain of product-oriented PSS enhancements. Therefore, in most cases (21) it is a matter of non-disruptive modifications of the firms' business models that fundamentally are comfortably rooted in the currently prevalent product-orientation culture that permeates all the manufacturing firms of the sample (see: low and low- medium business model conflicts in Table 2).

Tab. 2: Business model changes in the investigated firms

Company	Industry	Rev. (mio)	Value system	Sales model	Sales model changes	Value proposition orientation	Value proposition shift (PSS)	BM change scope	BM conflicts	Ambidexterity management
1	Professional equipment	3	OEM	Indirect	=	Product		Limited	Low	
2	Machine tools	8	OEM	Direct	=	Product		Limited	Low	
3	Professional equipment	6	OEM	Indirect	=	Product		Limited	Low	
4	Mechanical components	8	OES	Indirect	=	Product		Limited	Low	
5	Packaging machines	20	OEM	Direct	=	product		Limited	Low	
6	Packaging machines	50	OEM	Direct	=	Product	To result-oriented	Wide	Medium-high	Contextual
7	Inspection machines	37	OEM	Direct	=	Product		Limited	Low	
8	Professional equipment	105	OEM	Indirect	To direct	Product		Limited	Low-medium	
9	Heating control systems	48	OES	Indirect	=	Product		Limited	Low	
10	Heating devices	61	OEM	Indirect	To direct	Product		Limited	Low-medium	
11	Food machines	150	OEM	Indirect	=	Product		Limited	Low	
12	Home automation	130	OEM	Indirect	=	Product		Limited	Low	
13	Diagnosis machinery	90	OEM	Indirect	To direct	Product		Limited	Low	
14	Heating control systems	166	OES	Indirect	=	Product		Limited	Low	
15	Machine tools and plants	202	OEM	Direct	=	Product		Limited	Low	
16	Retail equipment	240	OEM	Direct	=	Product	To result-oriented	Wide	Medium-high	Contextual
17	Off-road automation	157	OES	Indirect	To direct	Product		Limited	Low-medium	
18	Water management devices	278	OEM	Indirect	=	Product		Limited	Low	
19	Heating components	276	OES	Indirect	To direct (planned)	Product		Limited	Low-medium	
20	Heating equipment	235	OES	Indirect	To direct (planned)	Product		Limited	Low	
21	Coffee and coffee machines	381	OEM	Indirect	=	Product		Limited	Low	
22	Retail equipment	225	OEM	Direct	=	Product	To result-oriented	Wide	Medium-high	Contextual
23	Packaging machines	219	OEM	Direct	=	Product	To result-oriented	Wide	High	Contextual
24	Home automation	211	OEM	Indirect	=	Product		Limited	Low	
25	Packaging machines	239	OEM	Direct	=	Product		Limited	Low	

Source: our elaboration

This situation is related to the fact that I4.0 technologies' impact on new business models depend heavily on the access to user-firms' data. Firms with a direct relation with final-user firms (that is firms with a direct sales model in Tables 1 and 2) are very well to offer new services destined to the final-user firms' processes, while in case of an indirect relationship that option is out of reach. That is why firms that belong to the latter case (OEMs with an indirect relation with final user firms or first/second tier OESs) are stuck in a position that only a very difficult downstream move can change: as one can see in Table 2, only 6 out of the 16 firms having an indirect access to user firms' data are making (or planning) such a step.

However, four firms are aimed at more sophisticated explorations: they are experimenting result-oriented PSS, challenging the established business model with performance-based contracting via IoT-based remote condition monitoring. These "challengers" - all OEMs with a custom or modular product and a direct sales model (see Table 2) - are in a privileged position in order to unleash the potential of I4.0, introducing advanced services directly related to the customers' needs instead of the mere product-oriented ones. As one can easily understand, those firms are truly facing a disruptive new business model: new forms of contractual agreements that move away from the ownership-based transactional sale of products represent a big challenge since the new offer is directly cannibalizing established sales, dangerously conflicting with the current business strategy. Let's consider, for instance, the revenue model implied in outcome-based contracts: here the billing mechanism is benchmarked on equipment's efficiency (i.e., uptime level) or to the actual rate of utilization of the product, suggesting firms to be very careful in approaching the topic (in particular, in industries in which the amount of capital expenditure underlying product manufacturing is significant).

In those cases, as we'll see, the critical capability firms have to master is to manage the conflicts that may arise between traditional and emergent business models. In particular, this is the area in which firms will have to succeed in managing duality and be ambidextrous, matching the exploration of the new and the exploitation of the old: the following sections will describe in depth the specific forms of ambidexterity management adopted by the sampled firms.

5. Business model innovation and contextual ambidexterity in Industry 4.0

To make a step further, in this section we'll focus on the challenger firms, adding some further information (see Table 3). In order to better understand the context in which challengers act, in the following paragraphs a more detailed description will be provided.

Company A is a small firm that produces machines and solutions for the packaging of tissue products, with strong capabilities related to innovation and service development. According to UCIMA (Italian Packaging Machinery Manufacturers' Association), the automatic packaging machinery industry is one of the most dynamic Italian industries: it counts

around 200-250 industrial companies with a total turnover of more than €7 billion, of which more than 80% comes from export. A employs 120 people, has a turnover of €50mio and is located in the so-called "Packaging Valley" in Emilia Romagna, a region with the highest concentration of packaging companies in the world (along with Lombardy, Piedmont and Veneto).

Company B belongs to the same industry, although to a different niche: located in Lombardy, it is a leader company in producing complete packaging systems and lines, especially for dried food. It is a medium-large enterprise that employs 1005 people in 4 different production locations in the world, with a total turnover of €219mio[2], with a strong and long-standing reputation in quality, innovation and customer service.

Company C and D are both medium to large firms belonging to the same industry. They are leader companies in the design, manufacturing, and installation of complete equipment for the retail sector: the production of commercial refrigerated furniture, systems and solutions is indeed an industry in which Italian firms can boost a long-standing tradition and reputation. Company C, located in one of the industrial clusters in the Veneto region, is now a global company that employs 697 people worldwide and totalizes €240mio revenues. C is renowned for its flexibility and its extensive product range, constantly updated in line with the evolution of big retail chains.

Company D is located in Lombardy and employs 975 people, totalizing €225mio revenues. It belongs to a dynamic group of firms focused on the production of furniture for the commercial sector, working with the world's grocery and FMCG (fast-moving consumer goods) leaders, to whom it offers personalized systems and turn-key solutions. As final remark - that as we'll see is connected to the way challengers manage ambidexterity in I4.0 - we must underline that all the companies operate in highly competitive markets facing international and global customers, that in many cases are MNEs with sophisticated needs and big bargaining power.

As we have seen previously, these firms started to manage the relation with key customers in a completely new way than in the past, linking (partially or totally) the revenues of the equipment supplied to the performance levels reached by their user-firms in their typical operations. In order to face those non-trivial changes, and protecting their extant business model from the potential disruptiveness of the change, challenger firms in our sample are adopting a contingent solution that is different from those envisioned by previous research: they are implementing a sort of "hidden" dual business model, since it is a particular form of exploration of the strategic duality related to digital technologies in which the new business model is acted in protected and bounded contexts. In fact, in order to contain the conflicts, controlling the potential disruptiveness and exploiting synergies among the extant and the new business model, our

[2] In this case, due to administrative balance sheet consolidation policies within corporate groups, we couldn't report facts and figures related specifically to the packaging system division within the firm's corporate group. For that reason, while the selected product line represents most of the business, facts here reported encompass also different divisions and product areas.

challengers are encapsulating the exploration space into selected supplier-customer relations, developing the new value proposition and the new business model only for selected customers (key customers).

As we'll see in detail, this solution entails specific forms of ambidexterity management that pertain to the broadened concept of contextual ambidexterity introduced earlier: to better understand this point, let's compare similarities and differences of the highlighted cases, to better investigate the reasons of this circumstance.

Table 3 reports challengers' data regarding the main traits the literature has highlighted in order to understand how to manage dual business models. Notwithstanding the unavoidable differences in industries, market conditions and firms' resources and capabilities, the cases share some similarities.

Tab. 3: Ambidexterity management mechanisms in challenger firms

Case	Industry	Rev. (mio)	Emp.	Categorial framing of BM innovation			Urgency of the BM change	Markets strategic relatedness	Potential disruptiveness of the new BM	Template of the new BM	Exploration breadth	Mechanism to exploit synergies	Type of customer	Strategic management of duality
				Threat *versus* opportunity	Proactive versus reactive	Short term versus long term								
A	Packaging machines	50	120	Opportunity	Proactive	Long	Low	High	High	None	High	Focus on key customers	Large MNE	"Hidden" dual business model
B	Packaging machines	219	1005	Opportunity	Reactive	Long	Low	High	High	None	High	Focus on key customers	Large MNE	"Hidden" dual business model
C	Retail equipment	240	697	Opportunity	Proactive	Long	Low	High	High	None	High	Focus on key customers	Large MNE	"Hidden" dual business model
D	Retail equipment	225	975	Opportunity	Reactive	Long	Low	High	High	None	High	Focus on key customers	Large MNE	"Hidden" dual business model

Source: our elaboration

Firstly, all the firms are facing extremely high levels of exploration breadth, since no template and no previous experience is present in relation to an experimental business model whose potential hostility to the established one is extreme. Moreover, all "pilot" projects involve key customers, being in fact sponsored by very large, sophisticated, and culturally advanced firms facing global markets, often leaders in their respective industry. In case B the trigger for exploring a new business has been the demand of a large firm concerned about the poor efficiency performance shown by its operations and looking for suppliers that are capable of helping to solve the problem. Company D started its business model innovation with one of its clients, a large multinational corporation with a great installed base and with specific needs related to the use of IoT technologies that did not find a proper solution. Cases A and C, on the contrary, show a more proactive strategic move, using selected customers for the piloting of new versions in order to have functional feedback.

Finally, all the firms share the same categorical framing regarding the role of digital technologies and I4.0 in their strategies: they classify the challenges they face prevalently as opportunities (even if they are completely aware of the risks) and adopt a long-term strategic horizon in order to evaluate actions and returns of the investments.

5.1 The inception of the new business model

Our challenger firms have begun a journey that has not yet ended, which is in line with the developmental character of I4.0 strategies, particularly those of digital servitization (Baines *et al.*, 2020; Zighan and Abualqumboz, 2022). An interesting difference that seems to emerge regards the inception of the project, or - so to say - the trigger that initiated the path. In fact, in the case of Company B the initial trigger for exploring a dual business model is an extant customer: a large firm operating in the food and beverage industry, worried of the bad efficiency performances showed by its operations and looking for suppliers capable to help to solve the problem and possibly to take over the entire process on its behalf.

Company D has started an important project with one of its clients, a key customer that, in this case, is the trigger of the exploration: a large MNE of the food and beverage industry with a huge installed base and with very specific needs related to the use of I4.0 technologies that haven't found a proper solution yet.

Cases A and C, on the contrary, show a more proactive strategic move: company A is conducting explorations in the possible uses of digital technologies since 2016, actively investing for the design of a possible new service solution; gradually the project becomes well-defined and larger, involving also external firms for the provision of the most technological requirements. Then, starting approximately from 2017, the company starts scouting its account portfolio in search of a suitable customer to test the system and "go live". As the company A's Business Development Manager says: "we are trying to invent new services that affect directly the customer's business; in a sense we are creating our future customer".

Company C is involved in an ongoing pilot experiment oriented to a specific niche of its market identified as possible target of a new value proposition. A large-scale retailer is the key customer involved in the project of envisioning a complete result-oriented solution capable of relieving the customer from any direct responsibility and direct activity on the machines during the use. "Finding out the right customer and the right way to explain the solution is the most difficult part", says the company C's Chief Technology Officer, recognizing that its market in general is not so prepared and sensitive, mainly for cultural reasons, even if first signs of dynamism are present. It is important to underline, however, that the difference between proactive and reactive approaches doesn't have to be neither overlooked nor overrated: in fact, companies B and D were being investigating possible new services to put in the offering for a while, and the call to action coming from a sophisticated and relevant customer occurred just at the right time, finding them "prepared" to seize it.

5.2 The context: people and organization

As far as organizational choices are concerned, reactive and proactive approaches show interesting differences in how the firm allocates resources on the projects.

Proactive approaches firstly identify a person, in general an internal professional coming from the sales department, that may be appointed to be the "Digital Transformation Manager" (DTM); at the beginning the structure at her/his disposal is quite lean, even if she/he has a blank proxy on the strategic exploration activities related to the new technological applications, regarding which she reports directly to the CEO. She can use some resources (human and physical) pertaining to internal offices (like, typically, the technical office, and the ICT department) negotiating duration and intensity with the specific manager in chief. Few stable resources are allocated initially to the venture, and the specific budget is quite limited. Progresses in the project, envisioned applications and the opportunity to develop internally some adaptations of off-the-shelf technologies can change this initial situation, mainly thanks to the abnegation and ability of the manager in chief (the DTM). Consequently, some specific professionals may be then allocated to the project: in case B, for example, a senior and a junior engineer compose the DTM's team. Further additions of people generally follow the gradual acceptation of the new "group" and the new project within the organization (especially at high strategic levels) and are related to competences and technologies necessary to implement mobile applications and data analysis (and in particular its most advanced evolutions of artificial intelligence and machine learning).

In the case of reactive approaches, the stakes at play are much clearer from the beginning and the company reacts promptly to the customer's request allocating resources in order to solve problems and find viable solutions as soon as possible. In case D for example, a new office (not a new division nor a new company) inside a pre-existent organizational structure (and the traditional business model) has been set up in order to face the challenge of I4.0: it is an "Innovation Centre" composed of 8 people with different competences, that interact with the R&D department in order also to give input for new product development activities. In case B, even if the in-house team is very small (2 people and the DTM), it is regularly connected to a larger group (10 people) that operates directly at the customers' premises and manages some of the operative tasks necessary to implement the result-oriented PSS. In that case, periodic meetings in-house can play as organizational integration mechanisms in order to align the whole team on the experimentation's developments.

Both approaches end up reserving the same treatment to organization and human resources when the exploration has reached a certain level of maturity. "At a certain point you have to go internally", says company A's Business Development Director, explaining the choice of hiring an expert in data analysis and business intelligence coming from the Apple Academy.

5.3 The client-supplier relation as a prototype

As we mentioned, no previous experience related to the main strategic challenges posed by the new business model is retrievable in the company's past or in the industry at large. A high level of uncertainty connotes the adopted solutions and their outcomes, putting firms in a highly risky situation: consequently, a high level of cooperation between supplier and

customer is a common trait of the cases. That cooperation takes different forms.

Firstly, in performance-oriented PSS the actual performances depend also from the customer's cooperation and ability in doing its part of the job. This result is consistent with findings in other studies on business model innovation based on I4.0 technologies (e.g., Müller, 2019; Paiola *et al.*, 2021). Secondly, the sustainability of the new business model may depend on the availability of the partners to share totally or partially the risks. In case B, for instance, the unprecedented features of contracts (conditions, service-level agreements, prices) and the disrupting shift in the revenue model, induced the key customer to agree to pay up-front the equipment involved in the pilot project. "That was the only way to make the outcome-based contracting economically sustainable for us" says the company B's CEO. Regarding the sustainability question, one important relational feature that every company underlines regards the length of supply contracts, whose duration must be consistent with the total value of the equipment.

A last aspect that is important to highlight relates to the metamorphosis of the firm's business model. As far as the outcome of the initial incubation phase and the further use of the experience gathered in the pilot experimentations is regarded, all the four firms testify for a common evolution of business model innovation towards a proactive approach, that involves a sort of replication of the experience for other customers. The search for more customers for the new PSS may also cross the boundaries of the firm's established market, as in case B: "We are trying to move towards new markets and fields of application … and I have to say that when we show our services and solutions to them, they say the product is interesting" (CEO).

6. Concluding remarks

This study seeks to shed light on how companies that are exploring the disruptive scenario of I4.0 are dealing with the duality posed by business model *Innovation,* in line with directions suggested by the literature on the subject (Meindl *et al.*, 2021).

6.1 Theoretical contribution

A first theoretical contribution is made by validating and refining the typology introduced in Figure 1 and regards the topic of disruptive business model innovations. In fact, in the I4.0 scenario: the exploratory process requires higher investments in knowledge, as there is no prior experience to exploit or imitate, and the exploration breadth is high; among the strategies hypothesized by Markides (2013), contextual ambidexterity is currently prevailing in the investigated firms, while at present we cannot foresee the evolution of the experimentation in subsequent phases: a prosecution of the contextual ambidexterity, a spatial separation or an ending of the duality through a business model metamorphosis (see type

IV in fig. 1); the innovation impacts directly on the firm's business model (Paiola and Gebauer, 2020; Paiola *et al.*, 2022), and may eventually consist in a metamorphosis of the old business model rather than the addition of a new one.

A further theoretical contribution of the paper concerns contextual ambidexterity, a concept as rich in charm as poorly explored in practice. The main finding of the empirical investigation is that all the challenger firms of our sample adopt a particular form of contextual ambidexterity, that differs from the one hypothesized by Gibson and Birkinshaw (2004) - according to which ambidexterity must be a quality of each individual in the organization - but is aligned with the recent evolution of the construct in the literature (Hu and Chen, 2016; Lavie *et al.*, 2010; Markides 2013; Winterhalter *et al.*, 2016). In fact, our challenger firms have made a selective choice, giving some employees (individually or in groups) the task of exploring the new opportunities through cooperation projects with the most advanced and important customers, maintaining a variable but always important connection to extant resources and competences in the organization. Since exploration involves specifically and uniquely key customers, this solution is a way of "hiding" the new business model inside a dyadic client- supplier relationship. This "hidden" dual business model is clearly a noteworthy strategy in terms of risk management and effectiveness, and cannot be defined as a second-best option for facing I4.0 disruptiveness.

Finally, our results are in line with those studies showing that some clients may be more useful than others in supporting the company's exploration process (Bednarek *et al.*, 2016; Im and Rai, 2008). A high level of cooperation between supplier and customer is a common trait of the cases. In addition to this evidence, our results show that exploration, since it involves specifically and uniquely key customers, becomes a way of "hidding" the new business model inside a dyadic client-supplier relationship. This "hidden" dual business model is clearly a noteworthy strategy in terms of risk management and effectiveness, and cannot be defined as a second-best option for facing I4.0 disruptiveness. Indeed, over time all the four firms follow a common evolutionary path of business model innovation towards a proactive approach, planning or trying somehow to replicate their initial experience also with other customers.

6.2 Managerial implications

In line with other recent studies (e.g., Frank *et al.*, 2019; Müller *et al.*, 2018; Paiola *et al.*, 2021), our research shows that firms that live up to meet the I4.0 challenge are still limited to few "fortunate" cases. However, making the title of one of those contributions our own, "fortune favors the prepared" (Müller *et al.*, 2018), underlining the role of strategic culture in preventing firms to make "fortune" with I4.0 (Paiola *et al.*, 2021).

Specifically, the results of our study indicate a main critical implication for managers of B2B manufacturing companies willing to achieve enterprise development via contextual ambidexterity within I4.0. Such companies tend to carry out an evolutionary, long-period and proaction-oriented

strategic approach which takes into account how customers' needs and industry requirements change over time, in particular after the progressive introduction and implementation of I4.0 technologies at the industry level. Therefore, managers need to understand which are the pace and extent of change for the various components of the corporate business model to innovate during each specific step of transition towards I4.0 technologies. For instance, the investments of specific resources, the development of new technology-based value propositions and the revision of the corporate value design could be incremental processes in those industrial contexts where customers and other suppliers are more laggards and reactive in the adoption and implementation of new technologies. In other words, the pace of disruption and the choices between a) proactiveness and reactiveness and b) exploration and exploitation should be also made by carefully considering the strategic approach of the main corporate customers and suppliers.

6.3 Limitations and further research

This study has three main limitations owing to its explorative nature. First, we have investigated firms involved in a transition phase: in particular, we can't tell what the outcome of the metamorphosis will be, and if it will be the same for every firm. Second, we didn't observe how contextual ambidexterity works in depth, for example regarding the role of individuals and groups, such as strategic managers (middle- and top-level) and top management teams. Third, BtoB manufacturing firms are only a portion, however relevant, of the I4.0 landscape. Clearly, each of these limitations would only be overcome by further research on the relationship between I4.0 and business model innovation.

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sinergie
italian journal of management

ISSN 0393-5108
ISSN 2785-549X
DOI 10.7433/s123.2024.04
pp. 71-94

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Digital entrepreneurial ecosystems: an empirical contribution using SMAA

Received
20th February 2023
Revised
30th May 2023
Accepted
19th February 2024

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Abstract

Framing of the research. *The concept of digital entrepreneurial ecosystems stands at the crossroads between the concepts of the digital ecosystem and the entrepreneurial ecosystem. We start with a summary of the data concerning the digital entrepreneurial pillars emerging in literature to provide robust and reliable measurement of digital entrepreneurial ecosystems.*

Purpose of the paper. *The aim of the paper is to measure and compare digital entrepreneurial ecosystems in European countries to ensure a productive context for new venture creation.*

Methodology*. We apply Stochastic Multicriteria Acceptability Analysis (SMAA) as a precise, robust, and reliable measurement approach to the Digital Economy and Society Index (DESI) data.*

Results*. The main contribution of this work is the provision of a probabilistic ranking that is more robust and reliable than the conventional single ranking derived from composite indices constructed with a single weight vector.*

Research limitations. *We applied SMAA allowing for a limited variation of the weights assigned in the computation of DESI. Allowing for a wider range of variation may provide further relevant insights. Furthermore, the database used for the operationalization of digital entrepreneurial ecosystem pillars may be enriched by adding further variables, thus enhancing the robustness of the analysis.*

Managerial implications. *Our work provides relevant managerial implications for policymakers and businesses. The analysis identifies strengths and weaknesses of the different countries thus offering useful guidelines for policy makers aiming to support territorial development and for businesses to identify market opportunities.*

Originality of the paper. *The originality of the paper lies in the application of SMAA methodology to digital entrepreneurial ecosystem literature, thus providing an empirical contribution to such a novel topic. We start from data used to compute the DESI index which, like most of the existing indices, is computed relying on fixed weights, thus being affected by a degree of subjectivity. The application of SMAA methodology allows us to consider how a variation in the assigned weights can affect the final ranking.*

Key words: *digital entrepreneurial pillars; digital society; entrepreneurship measurement framework; productive entrepreneurship; digital index; SMAA*

1. Introduction

The topic of digitalisation is growing in popularity in both the political and academic domains and has relevant implications in the field of entrepreneurial ecosystems as well. Digital technologies are indeed transforming entrepreneurship influencing both generating new entrepreneurial opportunities (Nambisan, 2017) and by impacting the entrepreneurial process itself (Ferreira *et al.*, 2019).

In this perspective, the level of digital maturity of an area may also be decisive for the emergence of new firms.

An entrepreneurial ecosystem can be defined as the combination of territorial actors and factors whose coordination and interaction support entrepreneurship (Corrente *et al.*, 2019; Neck *et al.*, 2004). GEM (Global Entrepreneurship Monitor) has followed the progress of nascent entrepreneurship in various countries over the past decade, evidencing that the growth rate and quantity of aspiring entrepreneurs vary between countries which differ in the level of economic and technological development (Cunningham and O'Kane, 2017).

The topic of entrepreneurial ecosystems as environments able to support new firms, has been of great interest not only for academics but also for both governmental and non-governmental entities and institutions, in the attempt to construct reliable and comparable rankings. Some examples are the World Bank, the World Economic Forum (WEF), and the Organization for Economic Co-operation and Development (OECD). However, some institutional reports and academic studies have also started to focus on digital entrepreneurship systems and technology-based entrepreneurship. A digital entrepreneurship system describes the environmental factors able to support digital entrepreneurship (Autio *et al.*, 2018b). Technology-based entrepreneurship describes the creation of new technology-based firms. These firms main features are: a growth potential, a need for external financing, the focus on niche markets with a high need of internationalization, the concentration in specific regions, the tendency to arise as spin-offs from existing organisations, the collaboration within an incubator or science park, the support to regional technology transfer and lastly the founders who are generally highly educated, and team based (Lindholm, 2017). Entrepreneurship has undergone a shift triggered by digitalisation and the application of digital technologies and infrastructures. Not only does digitalisation lead to radically reconsidering the way value is co-created and distributed at all levels in society, but it also affects all members of society, including present and aspiring entrepreneurs and their initiatives (Autio *et al.*, 2018a).

The academic literature in the field lacks empirical studies able to provide insights into digital entrepreneurial ecosystems to guide both entrepreneurs' and policymakers' investment decisions.

The present work consists in the application of Stochastic Multicriteria Acceptability Analysis (SMAA; Lahdelma *et al.*, 1998) as a precise, robust, and reliable measurement approach, to address the gap in the literature concerning a robust measurement of digital entrepreneurial ecosystems at the country level. By employing SMAA methodology, we provide a

considerable contribution to the evaluation, rating, and comparison of digital entrepreneurial ecosystems. When comparing and evaluating nations, a composite index based on the arithmetic mean of key factors of importance is typically used.

SMAA avoids the arbitrary choice of weights by considering all feasible vectors of weights and their corresponding rankings. From an operational point of view, the consideration of all feasible weight vectors is approximated by the random sampling of a large number of weight vectors. Consideration of all the weight vectors permits SMAA to supply a more realistic ranking of countries. It is rather misleading to assign a well-defined and stable ranking position to each country when this essentially depends on the importance assigned to each factor through the corresponding weight. In this regard, it is much more reliable to consider a probabilistic ranking that assigns a probability of each ranking position being attained. Moreover, SMAA reveals the strengths and weaknesses of each country in terms of factors with a larger weight determining a better or worse ranking position. This gives relevant indications to academics, policymakers, and practitioners, especially in terms of policy implications.

The Digital Economy and Society Index (DESI) is taken as a reference index for the measurement of digital entrepreneurial ecosystems. It consists of micro-level measurements of digitalisation for each European country, which are taken as the unit of analysis in this study.

The remaining part of the paper is organised as follows: section 2 presents the main contributions in the literature concerning entrepreneurial ecosystems and digital entrepreneurial ecosystems, section 3 describes the research design and presents the data used, section 4 illustrates the methodology adopted for the analysis, namely Multiple Criteria Decision Analysis and Stochastic Multicriteria Acceptability Analysis. The last 2 sections present the empirical results, the conclusions, and implications of the work.

2. Literature review

2.1 From ecosystems to entrepreneurial ecosystems

Roy Clapham first used the term "ecosystem" in 1930 to describe the physical and biological elements of an environment interacting with each other to shape a unit. The concept of ecosystem has subsequently been used as an analogy to describe different complex phenomena. An industrial ecosystem is defined as a system where the used materials are recycled infinitely and efficiently, thanks to the cooperation between the different parties (Frosch and Gallopoulos, 1989; Korhonen *et al.*, 2001). In the business environment, the concept of ecosystem has been used to identify a network of interacting firms.

Moore (1993) resumed the idea of an ecosystem by adopting the lens of business organisation studies. Moore (1996) defined a business ecosystem as "an economic community supported by a foundation of interacting organizations and individuals - the organisms of the business world" (Moore, 1996, p.9). By applying the concept of ecosystem to denote

business networks, he argues that the key to compete successfully for businesses is their belonging to an inter-sectoral ecosystem where they may cooperatively co-evolve, as well as gain skills and develop innovation.

The literature has therefore identified the analogy existing between business and biological ecosystems, defining the former as a business network characterised by interconnected actors which largely depend on each other for their survival (Peltoniemi and Vuori, 2004).

This analogy highlights similarities between business ecosystems and biological ecosystems existing in nature. Indeed, although businesses do not exactly imitate the way biological ecosystems work, the two types of ecosystems are thought to share some characteristics and follow the same rules (Lewin, 1999; Peltoniemi, 2006).

Another analogy that emerged is with the concept of service. A service ecosystem is defined as a "relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange" (Vargo and Lusch, 2016, p. 11).

The ecosystem concept has also been applied to the realm of entrepreneurship, referring to the capacity of a certain area to establish a network of actors and infrastructures that foster the creation and development of innovative business projects. Thus, the entrepreneurial ecosystem is a broad notion that encompasses a variety of different components, thus enlarging the focus traditionally placed by scholars on entrepreneurs as the only object of analysis, to investigate the role played by a variety of actors and elements in the entrepreneurial process (Van de Ven, 1993).

As a result, a comprehensive definition of the entrepreneurial ecosystem is that of "a set of interdependent actors and factors coordinated in a way that enables productive entrepreneurship". An entrepreneurial ecosystem is therefore finalised to the creation of new value for society at large. On the one hand, entrepreneurial ecosystems increase wealth and generate value for firms (economic impact). They contribute to regional innovation performance using the knowledge flows and value creation processes realized by the firms and institutions participating in the ecosystem itself (technological impact). On the other hand, both the monetary and non-monetary value generated is distributed among the members of the ecosystem itself, and this is referred to as societal impact (Audretsch *et al.*, 2019). In this perspective, entrepreneurial activity will serve more as an intermediary product of the system. This entrepreneurial activity can take different forms, including innovative start-ups, high-growth start-ups, and entrepreneurial employees.

The presence of some favorable factors such as investors, human resources, culture, infrastructure, institutions, regulatory and fiscal conditions, social and environmental quality, the capacity to generate innovation as well as the availability of real and potential know-how can contribute to making an ecosystem a suitable habitat for the development of new businesses. A recent but well-established body of literature has theoretically investigated which factors should be considered essential to foster entrepreneurship.

Van De Ven (1993) provided a detailed description of the industrial infrastructure that enables the establishment of new businesses. This type of infrastructure consists of institutional arrangements to regulate and standardise a newly developed technology, public resource endowments of fundamental scientific knowledge, financing mechanisms, a pool of competent labor, as well as proprietary research and development, manufacturing, marketing, and distribution functions. Cohen (2006) explored the nine primary aspects to be considered essential for an entrepreneurial ecosystem: they are referred to as the Informal Network, the Formal Network, the University, the Government, the Professional Service, the Support Services, the Capital Services, and the Talent Pool.

Another framework for the entrepreneurial ecosystem is the one outlined by Isenberg (2011), whose model includes six main relevant factors: a supportive culture, enabling policies and leadership, the availability of dedicated funding, relevant people, venture-friendly markets, and a wide range of institutional and infrastructural supports. Feld (2012) placed strong emphasis on the interaction among ecosystem actors (strong group of entrepreneurs, mentors, and advisors, and a robust network) as well as the accessibility to all types of necessary resources (talent, services, finance), while recognising an important supporting background role to government. According to Spigel (2017), an entrepreneurial ecosystem is the result of 11 cultural, social, and material elements that offer resources to make entrepreneurship thrive. These include a supportive culture, a history of entrepreneurship, worker talent, investment capital, networks, mentors and role models, policy and governance, universities, support services, physical infrastructure, and an open market. The above-described body of literature has therefore elaborated various lists of crucial or essential factors characterising an entrepreneurial ecosystem, from a theoretical perspective.

Ács *et al.* (2014) filled a gap in entrepreneurship research by focusing on country-level aspects of the entrepreneurial process and introducing the notion of National Systems of Entrepreneurship as systems of resource allocation where the driving force is represented by individuals pursuing new business opportunities. The results of this entrepreneurial activity are then regulated based on the institutional characteristics of the country. According to Stam (2015), within an entrepreneurial ecosystem, two main types of conditions can be identified: framework conditions and systemic conditions. Framework conditions include elements like demand, informal and formal institutions, culture, and physical conditions that can either enable or constrain human interaction. Instead, systemic conditions include aspects like networks of entrepreneurs, leadership, finance, talent, and knowledge as well as support services.

Shifting the focus from academic definitions toward the conceptualisations made by governmental and non/governmental agencies, according to the OECD, the existence of a legal framework, market conditions, availability and accessibility of financing, the generation and dissemination of knowledge, as well as entrepreneurial competencies and culture all contribute to the development of an entrepreneurial ecosystem. Based on official government statistics sources, the OECD

report "Entrepreneurship at glance" published in 2016 provides data at a global level on these entrepreneurial ecosystem factors for 50 countries. Rather than considering a single composite index, the OECD gives a series of indicators, as stated in the report itself:

"A defining characteristic of the program is that it does not provide a single composite measure of overall entrepreneurship within an economy. Rather, recognizing its multi-faceted nature, the program revolves around a suite of indicators of entrepreneurial performance that each provides insights into one or more of these facets" (OECD 2016, p. 9).

The Global Entrepreneurship Monitor (GEM) collects data on environmental factors that contribute to the formation of new firms. This data is gathered at a global level with the support of the National Experts Survey (NES) and allows different countries to be compared globally. The individual choice to launch a new business is indeed the result of many varying factors and it may have different consequences. Among these factors, the context is clearly decisive. The entrepreneurial environment or ecosystem plays a crucial role in influencing both the outcome of the decision (whether to start a new business or not) and the subsequent path of the potentially nascent entrepreneur in their attempt to progress from being an aspiring entrepreneur towards being the owner of a well-established firm. Apart from the support of family and friends, this shift is heavily dependent on some elements characterising the context. While it is nevertheless true that some entrepreneurial activities may prosper even under the toughest or most improbable conditions, it is undeniable that a supportive environment can inspire ambition and growth, thus facilitating the arduous shift from new to established firms. GEM proposes a wide categorisation of environmental factors, based on academic literature and on the results of its cross-country study: Entrepreneurial Finance & Ease of Access to Entrepreneurial Finance; Government Policy: Support and Relevance & Taxes and Bureaucracy; Government Entrepreneurial Programs; Entrepreneurial Education at School; Entrepreneurial Education Post-School; Research and Development Transfers; Commercial and Professional Infrastructure; Ease of Entry: Market Dynamics & Burdens and Regulation; Physical Infrastructure; Social and Cultural Norms.

In order to bypass the weighting issue, GEM suggests a variety of indicators rather than a single metric, similar to the OECD's approach. This decision entails giving up a single, comprehensive viewpoint in favor of a variety of signs that are more challenging to explain.

The World Economic Forum (WEF) evaluates the ecosystem competitiveness of 144 economies in its "Global Competitiveness Report", which provides useful insights into the main determinants of competitiveness. WEF suggests using 12 ecosystem competitiveness factors, including institutions, infrastructure, the macroeconomic environment, health and primary education, higher education and training, and market efficiency for goods, labour, and finances. Other factors include technological readiness, market size, business sophistication, and innovation. The 12 elements are measured individually and reported as well as consolidated into a single index.

A great effort has also been made by the World Bank with the "Ease of Doing Business" project. The findings provide results on two measures: the ease of doing business score and the ease of doing business ranking. The ease of doing business score evaluates an economy based on its performance in relation to the 41 measures of regulatory best practice for 10 Doing Business topics (Starting a business, Dealing with construction permits, Getting electricity, Registering property, Getting credit, Protecting minority investors, Paying taxes, Trading across borders, Enforcing contracts, Resolving insolvency). These scores benchmark economies according to their adherence to regulatory best practices and indicate how close they are to achieving the highest possible levels of regulatory performance (0 represents the lowest performance, 100 represents the highest). The ease of doing business ranking can take on values from 1 to 190, sorting countries based on how easy it is to do business in their territory (World Bank, 2020).

It is, however, necessary to note that most of the mentioned indices do not include weights, thus providing a simplified perspective of reality, or using weighting methods that are generally criticised because of their arbitrariness.

2.2 From entrepreneurial ecosystems to digital entrepreneurial ecosystems

Digitalisation and digital transformation are disrupting business processes and models as well as reshaping entrepreneurship. However, the intersection between the two concepts of digitalisation and the entrepreneurial ecosystem still seems to be understudied in academic literature, except for some contributions. In the digital economy, a large part of the emerging and successful new ventures leverages digital technologies to perform their activities.

Before dealing with the conceptualisation of the digital entrepreneurship ecosystem, it is necessary to clarify the idea of the digital ecosystem, which arose in the 2000s. A digital ecosystem can be defined as "a self-organizing, scalable and sustainable system composed of heterogeneous digital entities and their interrelations focusing on interactions among entities to increase system utility, gain benefits, and promote information sharing, inner and inter cooperation and system innovation" (Li *et al.*, 2012, p.119).

A relevant conceptualization in entrepreneurial literature was proposed by Autio *et al.* (2018b). The authors suggested that the evaluation of a digital entrepreneurial system should consider 4 general framework conditions as well as 4 systemic framework conditions. The general framework conditions are: (1) Culture and Informal Institutions, (2) Formal Institutions, Regulation, and Taxation, (3) Market Conditions, and (4) Physical Infrastructure. The degree of digitalisation of these conditions can be measured by associating each of them with a measure of the digital context. The systemic resource-related conditions are (1) Human Capital, (2) Knowledge Creation and Dissemination, (3) Finance, and (4) Networking and Support. They are supposed to vary depending on the stage of development of an entrepreneurial activity and, for this reason, they are differentiated into Stand-up, Start-up, and Scale-up stages.

According to Sussan and Acs (2017), from a theoretical point of view, the concept of a digital entrepreneurial ecosystem derives from the

intersection between the concepts of the digital ecosystem (Dini *et al.*, 2011; Weil and Woerner, 2015) and entrepreneurial ecosystem, as above conceptualised. The authors suggested that in understanding a digital ecosystem, digital technologies should be thought of as the non-living element, while people who make use of them as the living element. The two elements interact with each other, generating dynamics and changes that characterise the ecosystem itself. Consequently, the two fundamental components of a digital ecosystem are the digital infrastructure and the users. The entrepreneurial ecosystem is instead seen as made up of agents and institutions.

Digital infrastructure is defined as a socially integrated mechanical system comprising technology and human components, networks, systems, and processes that produce self-reinforcing feedback loops. By users, we mean anyone who has access to digital technologies. Consistently, according to Autio *et al.*, (2018a), entrepreneurship is impacted by digitalisation by means of what is referred to as digital affordance, the possibility to conduct wholly new activities or already existing ones in novel ways. The concept of affordance has its roots in the work by Gibson (1979) who raised the issue of affordance of natural objects. In Gibson's view, human beings and animals perceive natural objects differently depending on the possibilities these objects offer for action (e.g. a river may represent a place to drink for a buffalo while a rock may provide a shelter for a reptile) (Gibson, 1979). The term user refers to the entire population having access to digital technologies. In this context, characterised by an intense net of interactions within the digital community, some users may accidentally become entrepreneurs by creating novel goods or services that enrich and improve the ecosystem itself (Shah and Tripsas, 2007).

Sussan and Acs' model (2017) was subsequently resumed and refined by Song (2019), who conceptualises four main dimensions: (1) digital user citizenship, (2) digital technology entrepreneurship, (3) digital infrastructure governance, and (4) digital multisided platform.

Another attempt to define the novel concept of digital entrepreneurial ecosystems was made by Elia *et al.* (2020), who refer to it as the coalition of components, operating within a specific region, supporting the advancement of innovative businesses that want to capitalise on emerging opportunities stemming from digital technologies.

Furthermore, more recent contributions have investigated how digital technologies facilitate interconnections inside entrepreneurial ecosystems (Bouncken and Kraus, 2022) as well as the process of converting a conventional market into an entrepreneurial ecosystem through the use of digitalization and an e-commerce strategy (Song *et al.*, 2022). Lastly, Bejjani *et al.* (2023) proposed a broad conceptual framework exploring seven digital entrepreneurial ecosystem attributes: governance, actors, resources, architecture, complementarity, reach, and identification process.

The literature on digital entrepreneurial ecosystems is still on the rise. However, what emerges from the above presented overview is that most of the contributions are conceptual and there is a lack of empirical investigation in the field.

Torres and Godinho (2022) identified a gap in the need to evaluate how necessary each element of a digital entrepreneurial ecosystem is. However, to date, academic research has failed to produce methodologies for evaluating and comparing digital entrepreneurial ecosystems from different perspectives that can highlight the underlying factors.

Having identified this gap, the paper proposes the application of an accurate, robust, and reliable measurement technique, namely stochastic multicriteria acceptability analysis (SMAA). It considers the variability of weights that can be assigned to the different factors, producing a probabilistic ranking to obtain a comparison between the entrepreneurial ecosystems. This ranking is more reliable than a single ranking proposed by the usual composite indices that consider a single vector of weights.

3. Research design

The present contribution considers 33 indicators, grouped into 10 subdimensions and 4 dimensions summarising the most common digital entrepreneurial pillars emerging in literature. Data are gathered from the Digital Economy and Society Index (DESI) which provides information on the digital progress made by European countries.

We use DESI because it was developed in line with the objectives of the 2030 Digital Compass: the European Way for the Digital Decade Communication which defines the EU's vision for digital transformation to realise by 2030 and outlines specific digital goals.

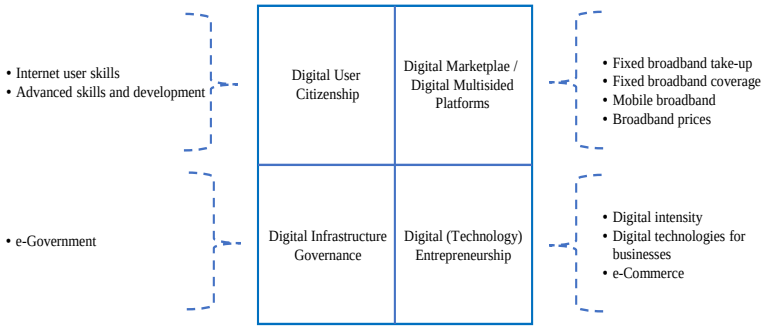
The raw data used to calculate the DESI, which also represents the input of our analysis, have been collected by the European Commission, by means of the competent authorities of each member state (the Directorate-General for Communications Networks, Content and Technology and Eurostat). Additionally, the Commission conducted ad hoc studies to supplement the data. Data collection and validation are described in detail in the methodological note (European Commission, 2021A).

The four cardinal points of this digital agenda are: a digitally skilled population and highly skilled digital professions; secure and sustainable digital infrastructures; digital transformation of businesses, and the digitalisation of public services (European Commission, 2021a). The DESI is built around them and is made up of four main dimensions: Human Capital, Connectivity, Integration of digital technology, and Digital public services. The index has a three-level structure, which means that for each dimension, a number of sub-dimensions and micro-level indicators are identified. Starting from the DESI index, the aim of the present paper is to provide an application of Stochastic Multicriteria Acceptability Analysis (SMAA; Lahdelma *et al.*, 1998) as a precise, robust, and reliable measurement methodology for the measurement of digital entrepreneurial ecosystems at the national level. We aim to compare different countries by evaluating, ranking, and comparing them as digital entrepreneurial ecosystems, by applying SMAA methodology.

Figure 1 represents the way in which already existing frameworks (Sussan and Acs, 2017; Song, 2019) can be integrated with the data collected

by the European Commission, with the aim to operationalise the four pillars of a digital entrepreneurial ecosystem and provide an evaluation of digital entrepreneurial ecosystems at a country level.

Fig. 1: Integrating Digital Entrepreneurial Ecosystem Framework (Sussan and Acs, 2017; Song, 2019) with DESI structure



Source: authors' own elaboration based on Sussan and Acs (2017), Song (2019) and European Commission (2021a)

The DESI index is a composite index (Greco *et al.*, 2019) assigning a value to each European Country based on thirty-three elementary criteria structured hierarchically and weighted as follows:

1. Human capital (g_1): 25%
   - 1.1 Internet users' skills ($g_{(1,1)}$): 50%
     - 1.1.1 At least basic digital skills ($g_{(1,1,1)}$): 50%
     - 1.1.2 Above basic digital skills ($g_{(1,1,2)}$): 25%
     - 1.1.3 At least basic software skills ($g_{(1,1,3)}$): 25%
   - 1.2 Advanced skills and development ($g_{(1,2)}$): 50%
     - 1.2.1 ICT specialists ($g_{(1,2,1)}$): 33.33%
     - 1.2.2 Female ICT specialists ($g_{(1,2,2)}$): 33.33%
     - 1.2.3 Enterprises providing ICT training ($g_{(1,2,3)}$): 16.67%
     - 1.2.4 ICT graduates ($g_{(1,2,4)}$): 16.67%
2. Connectivity ($g2$): 25%
   - 2.1 Fixed broadband take-up ($g_{(2,1)}$): 25%
     - 2.1.1 Overall fixed broadband take-up ($g_{(2,1,1)}$): 33.33%
     - 2.1.2 At least 100 Mbps fixed broadband take-up ($g_{(2,1,2)}$): 33.33%
     - 2.1.3 At least 1 Gbps take-up ($g_{(2,1,3)}$): 33.33%
   - 2.2 Fixed broadband coverage ($g_{(2,2)}$): 25%
     - 2.2.1 Fast broadband (NGA) coverage ($g_{(2,2,1)}$): 25%
     - 2.2.2 Fixed Very High-Capacity Network (VHCN) coverage ($g_{(2,2,2)}$): 50%
     - 2.2.3 Fibre to the precises (FTTP) coverage ($g_{(2,2,3)}$): 25%
   - 2.3 Mobile broadband ($g_{(2,3)}$): 40%
     - 2.3.1 5G Spectrum ($g_{(2,3,1)}$): 25%
     - 2.3.2 5G coverage ($g_{(2,3,2)}$): 50%
     - 2.3.3 Mobile broadband take-up ($g_{(2,3,4)}$): 25%
   - 2.4 Broadband prices ($g_{(2,4)}$): 10%
     - 2.4.1 Broadband price index ($g_{(2,4,1)}$): 100%
3. Integration of digital technology (g_3): 25%

3.1 Digital intensity ($g_{(3,1)}$):15%
3.1.1 SMEs with at least a basic level of digital intensity ($g_{(3,1,1)}$): 100%
3.2 Digital technologies for businesses ($g_{(3,2)}$): 70%
3.2.1 Electronic information sharing($g_{(3,2,1}$)): 10%
3.2.2 Social media ($g_{(3,2,2)}$): 10%
3.2.3 Big data ($g_{(3,2,3)}$): 20%
3.2.4 Cloud ($g_{(3,2,4)}$): 20%
3.2.5 AI ($g_{(3,2,5)}$): 20%
3.2.6 ICT for environmental sustainability ($g_{(3,2,6)}$): 10%
3.2.7 E-Invoices ($g_{(3,2,7)}$): 10%
3.3 E-Commerce ($g_{(3,3)}$) 15%
3.3.1 SMEs selling online ($g_{(3,3,1)}$): 33.33%
3.3.2 E-Commerce turnover ($g_{(3,3,2)}$): 33.33%
3.3.3 Selling online cross-border ($g_{(3,3,3)}$): 33.33%

4. Digital public services (g_4): 25%
4.1 e-Government ($g_{(4,1)}$): 100%
4.1.1 e-Government users ($g_{(4,1,1)}$): 14.29%
4.1.2 Pre-filled forms ($g_{(4,1,2)}$): 14.29%
4.1.3 Digital public services for citizens ($g_{(4,1,3)}$): 28.57%
4.1.4 Digital public services for businesses ($g_{(4,1,4)}$): 28.57%
4.1.5 Open data ($g_{(4,1,5)}$): 14.29%.

This means that Human capital, Connectivity, Integration of digital technology, and Digital public services are equally weighted. Under the Human capital macro-criterion, internet users' skills and Advanced skills and development have the same weight. The elementary criteria descending from a last, but one level criterion all have the same weights or double. For example, considering Internet users' skills, Above basic digital skills and At least basic digital content creation skills have the same weight (25%), while At least Basic Digital Skills has double the weight of the other two (50%).

Evaluations of the countries on the thirty-three elementary criteria are normalized to put them on the same [0,1] scale considering a minimum and a maximum value for each of them. Therefore, these evaluations are aggregated to obtain a comprehensive score on each macro-criterion and, at the global level.

Looking at the computation of the index, the following main issues can be underlined.

- *Normalization*: Many normalization techniques can be used to put all the evaluations on the same scale. However, different normalizations assign different values and, therefore, different aggregated values to the considered countries. Moreover, each normalization implies a loss of information concerning the original data.
- *Weighting*: As explained above, the DESI index is computed considering certain fixed weights for all criteria in the hierarchy. However, the choice of the weights is arbitrary, and different weight vectors would provide different scores to the considered countries and, therefore, different recommendations could be obtained.
- *Hierarchical structure*: The DESI index aggregates as a whole the evaluations on the thirty-three elementary criteria computing,

therefore, a global score taking all of them together. From a policy-making point of view, it would be useful to get a global level ranking as well as a ranking for each of the macro-criteria to obtain further insight into the weak and strong points of each country.

In this paper, we shall tackle the second and third issues. On the one hand, regarding the weighting issue, we shall consider a whole set of weight vectors and not only the one used to compute the DESI index. In this way, we shall show how a small variability in the weights attached to the criteria will imply a degree of variability in the ranking of the Countries. To this aim, we shall apply the Stochastic Multicriteria Acceptability Analysis (SMAA; Lahdelma *et al.*, 1998; Pelissari *et al.*, 2020). On the other hand, we shall apply the Multiple Criteria Hierarchy Process recently introduced in the literature to obtain a ranking on the comprehensive level as well as considering the 4 macro-criteria in the hierarchy.

4. Methodology. Multiple Criteria Decision Analysis and Stochastic Multicriteria Acceptability Analysis

In Multiple Criteria Decision Analysis (Greco *et al.*, 2016) a set of alternatives $A=\{\alpha,b,c,\ldots\}$ is evaluated on a set of criteria $G=\{g_1,\ldots,g_m\}$ to deal with a ranking, choice, or sorting problem (Roy, 1996). Several different MCDA methods have been presented in the literature and all of them aim to aggregate the evaluations of the alternatives to give a recommendation on the problem at hand. In particular, Multiple Attribute Value Theory (MAVT), through a value function, assigns a real number to each alternative being representative of its goodness concerning the considered problem. Among the possible value functions, the simplest and most used in practice is the weighted sum.

$$WS(a,\boldsymbol{w}) = WS(g_1(a),\ldots,g_m(a),w_1,\ldots,w_m) = \sum_{j=1}^{m} w_j \cdot g_j(a)\,.$$

Of course, the value assigned from the weighted sum to each alternative depends on the weights assigned to the criteria. SMAA was presented for the first time by Lahdelma, Hokkanen, and Salminen (1998). It produces information on the problem at hand considering a certain variability in the alternatives' evaluations as well as on the weights of the considered criteria (the parameters of the model, in general). In our case, we shall consider the same evaluations used in the DESI index and, therefore, we shall take into account a variability related only to the weights of criteria. Denoting by

$$\mathbf{W} = \left\{ (w_1,\ldots,w_m) \in R^m : w_j \geq 0 \text{ and } \sum_{j=1}^{m} w_j = 1 \right\}$$

the whole space of weights vectors that could be used, SMAA produces information in statistical terms considering a sampling of weights vectors in W. Fixed a certain alternative α and a weight vector $\mathbf{w}$, SMAA defines the following rank function

$$rank(a,\mathbf{w}) = 1 + \sum_{b \neq a} \rho\big(WS(b,\mathbf{w}) > WS(a,\mathbf{w})\big)$$

where $\rho(true)$=1 and $\rho(false)$=0. Denoting by W_{Sample} the set of weight vectors sampled from W, for each $\alpha,b \in$ A and each rank position s=1,…,|A| SMAA computes the following sets

$$\mathbf{W}^s(a) = \{\mathbf{w} \in \mathbf{W}_{Sample}: rank(a,\mathbf{w}) = s\}$$
$$\mathbf{W}(a,b) = \{\mathbf{w} \in \boldsymbol{W}_{Sample}: WS(a,\mathbf{w}) > WS(b,\mathbf{w})\}$$

and, therefore, the following indices:

- *The rank acceptability index, $b^s(\alpha)$*: it is the frequency with which a fills the position s and it is computed as

$$b^s(a) = \frac{|\mathbf{W}^s(a)|}{|\mathbf{W}_{Sample}|}.$$

It is a value in [0,1] and the best alternatives are those presenting a high-rank acceptability index for the first-rank positions,

- The central weight vector of a for position s is the barycenter of $\mathbf{W}^s(\alpha)$ and it is computed as the average, component by component, of the weight vectors in $\mathbf{W}^s(\alpha)$. It represents the average preferences giving to α position s,
- *The pairwise winning index, $p(\alpha,b)$*: it is the frequency with which a is preferred to b and it is computed as

$$p(a,b) = \frac{|\mathbf{W}(a,b)|}{|\boldsymbol{W}_{Sample}|}.$$

It is a value in [0,1] and the greater $p(\alpha,b)$, the more a is preferred to b.

Based on the rank acceptability indices, following Corrente *et al.*, 2019, the following additional information can be computed for each α:

- The lowest and the greatest rank positions that can be obtained by α,
- The three most frequent positions that can be obtained by α.

In our context, we shall assume that the weight assigned to the elementary criteria as well as to the second and third-level criteria are the same used in the computation of the DESI index and illustrated in the previous section, while we considered different weights for the four macro-criteria. In addition to the case in which the four criteria are equally weighted, we assumed that the weight of each macro-criterion can vary in the interval [20%,30%].

In the case of practical problems, criteria are not sited at the same level, but they are organized hierarchically. It is therefore possible to underline a root criterion, being the main objective of the problem; some first-level criteria having sub-criteria descending from them; finally, the elementary criteria on which the evaluation of the alternatives is provided are placed at the bottom of the hierarchy.

The MCHP was presented by Corrente, Greco and Słowiński (2012) to deal with problems in which criteria are structured hierarchically. The main objective of MCHP is therefore providing recommendations both at the global level, that is, considering all criteria simultaneously, and considering each node of the hierarchy.

From a computational point of view, denoted by g_r a certain criterion in the hierarchy, MCHP computes the weighted sum of an alternative α on g_r considering only the elementary criteria descending from it, that is,

$EL(g_r) \subseteq \{g_1,\ldots,g_m\}$. The weighted sum of α on criterion g is then computed as follows:

$$WS_{g_r}(a,\mathbf{w}) = \sum_{g_t \in EL(g_r)} g_t(a) \cdot w_t .$$

All indices of SMAA can easily be computed defining for each a,b∈A, for each rank position s and each macro-criterion g_r the following sets:

- $\boldsymbol{W}^s_{g_r}(a) = \{\mathbf{w} \in \mathbf{W}_{Sample} : rank(a,\mathbf{w},g_r) = s\}$ where
  $rank(a,\mathbf{w},g_r) = 1 + \sum_{b \neq a} \rho\big(WS_{g_r}(b,\mathbf{w}) > WS_{g_r}(a,\mathbf{w})\big)$
- $\mathbf{W}_{g_r}(a,b) = \{\mathbf{w} \in \boldsymbol{W}_{Sample} : WS_{g_r}(a,\mathbf{w}) > WS_{g_r}(b,\mathbf{w})\}$.

Therefore, the typical indices of SMAA are extended to the MCHP context as follows:

- The partial rank acceptability index of a for criterion g_r and position $s \in \{1,\ldots,m\}$:

$$b^s_{g_r}(a) = \frac{\left|\boldsymbol{W}^s_{g_r}(a)\right|}{\left|\boldsymbol{W}_{Sample}\right|}$$

- The partial central weight vector of α for criterion g_r and for position s∈{1,…,m}: It is computed as the average, component by component, of the weight vectors in $\boldsymbol{W}^s_{g_r}(\alpha)$,
- The partial pairwise winning index for criterion g_r, $p_{g_r}(\alpha,b)$:

$$p_{g_r}(a,b) = \frac{\left|\mathbf{W}_{g_r}(a,b)\right|}{\left|\mathbf{W}_{Sample}\right|}.$$

5. Empirical analysis and results

By applying SMAA to the DESI input data, the rank acceptability indices, the pairwise winning indices, and the central weight vectors are obtained.

Table 1 reports the frequency with which a given country achieves each of the possible positions in the overall ranking, from the 1st to the 27th (which is the total number of countries considered). The results show that Denmark and Finland attain the 1st position with a frequency of 38,82 and 61,18 respectively. In contrast, Bulgaria and Greece are the 26th position with a frequency of 90,86 and 9,15 while the last position is occupied by Romania with a frequency of 100. The results are enriched by the figures given in Tables 2 and 3. Table three shows the best and the worst positions attainable for each country, based on the results of the rank acceptability indices.

Tab. 1: Rank acceptability index

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14
Austria	0	0	0	0	0	0	0	0	2,987	96,931	0,082	0	0	0
Belgium	0	0	0	0	0	0	0	0	0	0	0	0	0,022	0,285
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Croatia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Czechia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Denmark	38,824	61,176	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	97,013	2,939	0,047	0,001	0	0
Finland	61,176	38,824	0	0	0	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	0	0	0	0,032	41,164	24,55	31,821	2,433
Germany	0	0	0	0	0	0	0	0	0	0,036	4,955	18,605	33,514	42,705
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0	0	0	0	0	0	0	0	0,011
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0,018	15,501	13,377	16,405	54,513
Luxembourg	0	0	0	0	0	0	0	100	0	0	0	0	0	0
Malta	0	0	0	0	0	54,581	45,419	0	0	0	0	0	0	0
Netherlands	0	0	100	0	0	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0,053
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0,044	38,251	43,467	18,238	0
Spain	0	0	0	0	0	45,419	54,581	0	0	0	0	0	0	0
Sweden	0	0	0	100	0	0	0	0	0	0	0	0	0	0

	#15	#16	#17	#18	#19	#20	#21	#22	#23	#24	#25	#26	#27
Austria	0	0	0	0	0	0	0	0	0	0	0	0	0
Belgium	25,621	34,063	28,195	5,586	4,815	1,413	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0	0	9,145	90,855	0
Croatia	0	0	0	0,086	1,269	10,923	87,722	0	0	0	0	0	0
Cyprus	0	0	0,495	3,784	8,642	75,839	11,24	0	0	0	0	0	0
Czechia	0	0,192	7,257	56,113	35,231	1,207	0	0	0	0	0	0	0
Denmark	0	0	0	0	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0	0	0	0	0
France	0	0	0	0	0	0	0	0	0	0	0	0	0
Germany	0,181	0,004	0	0	0	0	0	0	0	0	0	0	0
Greece	0	0	0	0	0	0	0	0	0	2,503	88,352	9,145	0
Hungary	0	0	0	0	0	0	0	70,981	29,019	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	4,143	8,636	25,969	21,108	39,434	0,698	0,001	0	0	0	0	0	0
Latvia	4,999	22,626	37,486	13,323	10,609	9,92	1,037	0	0	0	0	0	0
Lithuania	0,186	0	0	0	0	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0	0	0	0
Netherlands	0	0	0	0	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0	97,497	2,503	0	0
Portugal	64,87	34,479	0,598	0	0	0	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0	0	0	0	0	0	100
Slovakia	0	0	0	0	0	0	0	29,019	70,981	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: our elaboration

Tab. 2: Best-worst position

	Best Position	%	Worst Position	%
Austria	9	2,987	11	0,082
Belgium	13	0,022	20	1,413
Bulgaria	25	9,145	26	90,86
Croatia	18	0,086	21	87,72
Cyprus	17	0,495	21	11,24
Czechia	16	0,192	20	1,207
Denmark	1	38,82	2	61,18
Estonia	9	97,01	12	0,001
Finland	1	61,18	2	38,82
France	10	0,032	14	2,433
Germany	10	0,036	16	0,004
Greece	24	2,503	26	9,145
Hungary	22	70,98	23	29,02
Ireland	5	100		
Italy	14	0,011	21	0,001
Latvia	15	4,999	21	1,037
Lithuania	10	0,018	15	0,186
Luxembourg	8	100		
Malta	6	54,58	7	45,42
Netherlands	3	100		
Poland	24	97,5	25	2,503
Portugal	14	0,053	17	0,598
Romania	27	100		
Slovakia	22	29,02	23	70,98
Slovenia	10	0,044	13	18,24
Spain	6	45,42	7	54,58
Sweden	4	100		

Source: our elaboration

Tab. 3: Most frequent position

	Most frequent 1	%	Most frequent 2	%	Most frequent 3	%
Austria	10	96,931	9	2,987	11	0,082
Belgium	16	34,063	17	28,195	15	25,621
Bulgaria	26	90,855	25	9,145		
Croatia	21	87,722	20	10,923	19	1,269
Cyprus	20	75,839	21	11,24	19	8,642
Czechia	18	56,113	19	35,231	17	7,257
Denmark	2	61,176	1	38,824		
Estonia	9	97,013	10	2,939	11	0,047
Finland	1	61,176	2	38,824		
France	11	41,164	13	31,821	12	24,55
Germany	14	42,705	13	33,514	12	18,605
Greece	25	88,352	26	9,145	24	2,503
Hungary	22	70,981	23	29,019		
Ireland	5	100				
Italy	19	39,434	17	25,969	18	21,108
Latvia	17	37,486	16	22,626	18	13,323
Lithuania	14	54,513	13	16,405	11	15,501
Luxembourg	8	100				
Malta	6	54,581	7	45,419		
Netherlands	3	100				
Poland	24	97,497	25	2,503		
Portugal	15	64,87	16	34,479	17	0,598
Romania	27	100				
Slovakia	23	70,981	22	29,019		
Slovenia	12	43,467	11	38,251	13	18,238
Spain	7	54,581	6	45,419		
Sweden	4	100				

Source: our elaboration

As already evidenced, Denmark attains the 1st position with a frequency of 38,82 and Finland with a frequency of 61,18. These are the only two countries which attain the optimal position. This means that there is at least one weight vector for which they turn out to occupy the best position in the ranking and, thanks to the adoption of SMAA methodology, we are also able to calculate the probability of occupying a given position. Therefore, even though both countries can range from the first (best) to the second (worst) position, the above-mentioned probabilities lead us to deduce that, given the higher probability for Finland to attain the first position compared to the probability for Denmark, there is a larger share of weight vectors for which Finland can occupy the first position.

As far as the last positions are concerned, the 23rd is the worst position potentially attainable by Hungary and Slovakia with a frequency of 29,02 and 70,98 respectively while the last position is occupied by Romania with a frequency of 100. Table 3 presents the most frequent position, i.e., the mode, for each country. The most frequent position for Finland is 1st, for Denmark is 2nd, for Netherlands is 3rd (100%), for Sweden is 4th (100%), for Ireland is 5th (100%), for Malta is 6th (54,58%), and so on. The table also contains the second and third most frequent positions for each country.

Table 4 presents the pairwise winning index for all the possible pairs of countries. This index represents the frequency with which a country is preferred to another. For example, Finland is preferred to all the other countries with a frequency of 100% apart from Denmark, in comparison to which Finland is preferred with a frequency of 61,18%. This is an important insight, considering that Finland and Denmark are the two overall best-performing countries.

Another example is that Italy is preferred to Croatia, and Cyprus with a frequency of 99,3% and 99,94% respectively; Portugal is preferred to Italy (95,6%). Moreover, a significant insight is linked to the strength of the preferences. While, on the one hand, some preferences are strong enough to denote an almost undeniable direction of the preference itself, on the other hand, there are cases in which the advantage of one country over another is quite small. For example, comparing Slovenia to France, it turns out that Slovenia is preferred to France for 54,05% of the weight vectors but, for the remaining 45,95%, the preference is inverted.

However, apart from the global indices, more detailed additional information can be extracted by applying SMAA. In Tables 5, 6, 7, and 8, we present the cases of Italy, Ireland, Romania and Finland. We selected 4 countries for the limits of this study, but the same tables are available for all 27 countries. These tables are important for policymakers since they show the barycenters (central weight vectors) for the various positions, thus revealing which aspects are mainly responsible for a country's ranking. The central weight vector is the representation of how important the factors are in influencing the possibility of the country to attain the various positions in the ranking. In other words, the results are able to throw light on the strengths and weaknesses of each individual country.

Tab. 4: Pairwise winning index

	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czechia	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Netherlands	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden
Austria	0	100	100	100	100	100	0	2,987	0	99,98	100	100	100	0	100	100	99,982	0	0	0	100	100	100	100	99,956	0	0
Belgium	0	0	100	100	97,946	92,673	0	0	0	0	0,186	100	100	0	80,849	68,799	0,145	0	0	0	100	26,195	100	100	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	9,145	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Croatia	0	0	100	0	11,454	0	0	0	0	0	0	100	100	0	0,703	1,562	0	0	0	0	100	0	100	100	0	0	0
Cyprus	0	2,054	100	88,546	0	4,802	0	0	0	0	0	100	100	0	0,059	10,994	0	0	0	0	100	0	100	100	0	0	0
Czechia	0	7,327	100	100	95,198	0	0	0	0	0	0	100	100	0	43,376	24,095	0	0	0	0	100	0	100	100	0	0	0
Denmark	100	100	100	100	100	100	0	100	38,824	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Estonia	97,013	100	100	100	100	100	0	0	0	99,988	99,964	100	100	0	100	100	100	0	0	0	100	100	100	100	99,999	0	0
Finland	100	100	100	100	100	100	61,176	100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
France	0,02	100	100	100	100	100	0	0,012	0	0	85,614	100	100	0	100	100	72,943	0	0	0	100	100	100	100	45,952	0	0
Germany	0	99,814	100	100	100	100	0	0,036	0	14,386	0	100	100	0	100	100	55,234	0	0	0	100	99,986	100	100	16,088	0	0
Greece	0	0	90,855	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,503	0	100	0	0	0	0
Hungary	0	0	100	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	100	0	100	70,981	0	0	0
Ireland	100	100	100	100	100	100	0	100	0	100	100	100	100	0	100	100	100	100	100	0	100	100	100	100	100	100	0
Italy	0	19,151	100	99,297	99,941	56,624	0	0	0	0	0	100	100	0	0	35,453	0,011	0	0	0	100	4,404	100	100	0	0	0
Latvia	0	31,201	100	98,438	89,006	75,905	0	0	0	0	0	100	100	0	64,547	0	0	0	0	0	100	5,078	100	100	0	0	0
Lithuania	0,018	99,855	100	100	100	100	0	0	0	27,057	44,766	100	100	0	99,989	100	0	0	0	0	100	99,959	100	100	17,904	0	0
Luxembourg	100	100	100	100	100	100	0	100	0	100	100	100	100	0	100	100	100	0	0	0	100	100	100	100	100	0	0
Malta	100	100	100	100	100	100	0	100	0	100	100	100	100	0	100	100	100	100	0	0	100	100	100	100	100	54,581	0
Netherlands	100	100	100	100	100	100	0	100	0	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	100
Poland	0	0	100	0	0	0	0	0	0	0	0	97,497	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Portugal	0	73,805	100	100	100	100	0	0	0	0	0,014	100	100	0	95,596	94,922	0,041	0	0	0	100	0	100	100	0	0	0
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovakia	0	0	100	0	0	0	0	0	0	0	0	100	29,019	0	0	0	0	0	0	0	100	0	100	0	0	0	0
Slovenia	0,044	100	100	100	100	100	0	0,001	0	54,048	83,912	100	100	0	100	100	82,096	0	0	0	100	100	100	100	0	0	0
Spain	100	100	100	100	100	100	0	100	0	100	100	100	100	0	100	100	100	100	45,419	0	100	100	100	100	100	0	0
Sweden	100	100	100	100	100	100	0	100	0	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	0

Source: our elaboration

Looking at table 5, it starts with the 14th position which is the best position possibly attainable for Italy. Although the differences are not so sharp, we can make some relevant considerations. First of all, focusing on "Digital technologies for businesses", we can note how, going from the worst to the best position, the importance of these factors increases. Similarly, an enhancement in the positions is also gained with the growing importance of "Internet users' skills". This means that these factors can be considered as a strength and investing in these areas would avoid losing ground. The policymaker should implement actions to improve these aspects in order not to lose ground. Looking at the differences between the best and the worst position (first and last row), it is also worth noting that an increase in the weight of "Advanced skills and development", "Fixed broadband coverage", "Human capital" and "Digital public services" leads the country to move down in the ranking, which suggests that these factors are weaknesses when investing in getting a better positioning. As for Ireland and Romania (Tables 6 and 7), they always maintain the same position (5th and 27th respectively). Looking at Table 8 for Finland, the Dimension "Human capital" can be considered as a strength while "Connectivity" is a weakness. Although keeping in mind that this country is the best performer, it could be valuable to know that there is room for improvement in connectivity.

Digital skills can therefore be considered a key factor for the improvement of a digital entrepreneurial ecosystem. Although the role of digital skills as a driver of innovative performance has been widely investigated (Scuotto *et al.*, 2021), they may turn out to be relevant for new firms' development as well.

Tab. 5: Barycenters for all positions (Italy)

Position	Internet users skills	Advanced skills and development	Fixed broadband take-up	Fixed broadband coverage	Mobile broadband	Broadband prices
14	0,52	0,48	0,28	0,21	0,44	0,06
15	0,50	0,50	0,23	0,22	0,43	0,12
16	0,50	0,50	0,24	0,24	0,42	0,10
17	0,50	0,50	0,25	0,25	0,41	0,10
18	0,50	0,50	0,25	0,26	0,39	0,10
19	0,50	0,50	0,25	0,26	0,39	0,10
20	0,52	0,48	0,27	0,27	0,38	0,08
21	0,45	0,55	0,28	0,30	0,37	0,05

Position	Digital intensity	Digital technologies for businesses	e-Commerce	Human capital	Connectivity	Integration of digital technology	Digital public services
14	0,17	0,72	0,11	0,21	0,30	0,29	0,20
15	0,16	0,70	0,14	0,22	0,29	0,27	0,22
16	0,15	0,70	0,14	0,24	0,29	0,25	0,23
17	0,15	0,70	0,14	0,24	0,26	0,26	0,23
18	0,15	0,70	0,14	0,24	0,25	0,26	0,26
19	0,15	0,70	0,16	0,27	0,23	0,24	0,26
20	0,13	0,69	0,18	0,30	0,21	0,25	0,24
21	0,16	0,66	0,18	0,30	0,20	0,21	0,29

Source: our elaboration

Tab. 6: Barycenters for all positions (Ireland)

Position	Internet users skills	Advanced skills and development	Fixed broadband take-up	Fixed broadband coverage	Mobile broadband	Broadband prices
5	0,50	0,50	0,25	0,25	0,40	0,10

Position	Digital intensity	Digital technologies for businesses	e-Commerce	Human capital	Connectivity	Integration of digital technology	Digital public services
5	0,15	0,70	0,15	0,25	0,25	0,25	0,25

Source: our elaboration

Tab. 7: Barycenters for all positions (Romania)

Position	Internet users skills	Advanced skills and development	Fixed broadband take-up	Fixed broadband coverage	Mobile broadband	Broadband prices
27	0,50	0,50	0,25	0,25	0,40	0,10

Position	Digital intensity	Digital technologies for businesses	e-Commerce	Human capital	Connectivity	Integration of digital technology	Digital public services
27	0,15	0,70	0,15	0,25	0,25	0,25	0,25

Source: our elaboration

Tab. 8: Barycenters for all positions (Finland)

Position	Internet users skills	Advanced skills and development	Fixed broadband take-up	Fixed broadband coverage	Mobile broadband	Broadband prices
1	0,50	0,50	0,25	0,25	0,40	0,11
2	0,50	0,50	0,25	0,26	0,40	0,09

Position	Digital intensity	Digital technologies for businesses	e-Commerce	Human capital	Connectivity	Integration of digital technology	Digital public services
1	0,15	0,70	0,15	0,26	0,23	0,25	0,25
2	0,15	0,70	0,15	0,23	0,28	0,25	0,24

Source: our elaboration

6. Implications and concluding remarks

Entrepreneurship is a complex phenomenon, and many different factors may exert influence on it in a given entrepreneurship ecosystem. Evaluating the ability of a territory to encourage and support entrepreneurial initiatives becomes even more challenging in the digital era, where many entrepreneurial activities are digital-oriented.

The implications of the present work are both theoretical and practical. From a theoretical perspective, the most relevant contribution deriving from the application of SMAA to DESI data consists in the creation of a

probabilistic ranking that is more robust and reliable than the conventional single ranking derived from composite indices constructed with a single weight vector. Most of these indices, including DESI, are indeed computed relying on fixed weights identified by a panel of experts and are, for this reason, affected by a degree of subjectivity. SMAA allows us to consider how a variation in the assigned weights can affect the final ranking.

These results have relevant practical implications for both policymakers and businesses. On the one hand, the identification of strengths and weaknesses of the different countries provides useful guidelines for policymakers' decisions aiming to support territorial development.

From the present analysis, policymakers can obtain information both in relation to the entrepreneurial ecosystem of their own country and, in general, in relation to the most important environmental factors affecting entrepreneurship.

Measuring, understanding, and comparing the entrepreneurial ecosystem of their own country is critical to the momentum and maturity of policymakers. We have offered information on each specific country that could help policymakers define appropriate strategies to enhance and sustain strengths and protect from the negative effects of weaknesses. This puts the country in a position that enables it to attain better performance compared to other countries. In addition, the paper provides policymakers with robust general indications on the most relevant digital factors affecting entrepreneurship.

On the other hand, the present study can support businesses in identifying market opportunities to develop enabling technologies for the improvement of digital entrepreneurial ecosystems. Therefore, it may be relevant from an entrepreneurial decision-making and entrepreneurial behaviour perspective. Entrepreneurs or aspiring entrepreneurs could leverage this kind of information to make more informed investment decisions, based on clearer identification of market opportunities, given the current situation of the different countries, their strengths, and their weaknesses.

The paper has some limitations. Specifically, it is based on a single dataset. Despite DESI being considered a valid and reliable source of data, future developments of the study may rely on different sources.

Furthermore, some future research directions can be identified. We applied SMAA allowing for a limited variation of the weights assigned in the computation of DESI. This, however, produced some considerable fluctuations in the position of various countries (i.e. Italy, originally assigned to the 18th position, turns out to attain positions from the 14th to the 21st). Future applications may consider a broader range of weights, thus providing even more relevant changes in the ranking. Other datasets could also be used to enhance robustness. In addition, from a methodological point of view, we intervened on weights assignment and on the hierarchical structure of the index, but it is also possible to intervene on normalisation (both adopting a different normalisation method or applying a model that does not take normalisation into account) and on the interaction between criteria as an improvement opportunity, reconsidering the DESI methodological note.

Future research could validate such results by applying SMAA to various other entrepreneurial ecosystem factors, not yet analysed by DESI. It should also be noted that the analysis is based on the evaluations of the countries for a single year, namely 2021. Thus, future research could develop a dynamic analysis studying how the computed data evolve over time. Another issue that could be considered is the consideration of more advanced models that permit the analysis of the possible interaction between factors (Angilella *et al.*, 2015). Finally, we hope that in taking inspiration from this contribution, future studies might apply SMAA to the managerial field, making a substantial contribution to the evolution of the discipline.

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sinergie
italian journal of management

ISSN print 0393-5108
ISSN online 2785-549X
DOI 10.7433/s123.2024.05
pp. 95-119

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Artificial intelligence in personal development from cradle to grave: a comprehensive review of HRD literature[1] [2]

Received 7th March 2023
Revised 15th May 2023
Accepted 31th January 2024

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Abstract

Framing of the research. *Artificial intelligence (AI) is transforming the way organisations manage human resources, injecting new capabilities into human resource management (HRM). There is a pressing need to examine new and more effective approaches to human resource development (HRD).*

Purpose of the paper. *This paper aims to shed light on current knowledge of AI in the HRD domain, developing a comprehensive view of its role in the employee's journey.*

Methodology. *Keyword co-occurrence analysis and bibliographic coupling analysis were performed on a total of 151 papers published between 2002 and 2022. A similarity visualisation programme (VOSviewer) was used to showcase the results visually.*

Results. *The findings highlight the top five authors, sources, papers, and institutions in terms of the prolificacy of contributions in the field. The relevant contribution of this study is the identification and classification of the main topics and research streams in the academic literature. Five main bibliographic clusters are identified, unveiling the five most prominent topics in the field: i) AI in HR and contextual factors; ii) AI in education and future skills; iii) AI Coaching with chatbots; iv) AI in HR recruitment and training; v) AI in soft skills development.*

Research limitations. *It should be acknowledged that the findings are rooted in one database, Scopus, and only publications in English were considered.*

Managerial implications. *We offer three theoretical and institutional implications for advancing further research on AI in HRD. Furthermore, we outline six major takeaways and future lines of research stemming from our findings, resulting in a novel framework that can also be of practical interest to companies.*

Originality of the paper. *This is the first bibliometric study in the HRD and AI field from the viewpoint of personal development. Thus, we provide a first systematisation of the contributions developed in the last twenty years in this novel field of research.*

[1] This paper is the result of the joint effort of three authors: Francesco Laviola, Nicola Cucari, and Harry Novic. In the manuscript, however, section §1 may be attributed to Nicola Cucari and Francesco Laviola, sections §2, §3, §4 may be attributed to Francesco Laviola, and section §5 may be attributed to Francesco Laviola, Nicola Cucari, and Harry Novic.

[2] This work was financially supported by the Italian Ministry of University and Research under the National Operative Programme on Research and Innovation 2014–2020, Grant number DOT1326HYC-4; Sapienza University of Rome under the University Research Call 2022, Grant number AR1221816C0D000A; Sapienza University of Rome under the University Research Call 2023, Grant number AR123188AC0A2AF4.

sinergie
italian journal of management
Vol. 42, Issue 1, 2024

Key words: *artificial intelligence; human resource management; human resource development; personal development; literature review; bibliometric analysis*

1. Introduction

The advancement of artificial intelligence (AI)-computing technologies that simulate or imitate human-like intelligent behaviour-is transforming the way human resources are managed in organisations, introducing new capabilities in human resource management (HRM) (Sivathanu and Pillai, 2018; Vrontis *et al.*, 2022).

For example, Strohmeier and Piazza (2015) studied six key scenarios of AI in HRM, including turnover prediction using artificial neural networks; candidate search using knowledge-based search engines; staff rostering using genetic algorithms; human resource (HR) sentiment analysis using text mining; resume data acquisition using information extraction; and employee self-service using interactive voice response.

According to Makridakis (2017), the AI revolution seeks to replace, augment, and amplify tasks traditionally performed by humans, thereby becoming a formidable rival to human labour. As a result, AI is poised to support all aspects of human resource development (HRD) (Sivathanu and Pillai, 2018), especially those aspects related to training and development, defined as the "*process of systematically developing expertise in individuals for the purpose of improving performance*" (Swanson, 1995, p. 218). It is crucial to provide employees with opportunities for personal development-"*to acquire and develop valuable resources in the form of skills, abilities and knowledge*" (Fletcher, 2019, p. 5)-within HRM, because it helps to create a competitive advantage (Lee and Bruvold, 2003).

In a rapidly changing economy, companies invest in electronic HR systems that support the personal development of employees and change their approach to learning (Lejeune *et al.*, 2021).

In this context, one critical area is the implementation of appropriate learning strategies for employees. Social and soft skills, as opposed to hard skills, are increasing their importance in the HR scenario, and this paper aims to focus specifically on them, not from the classical perspective of de-skilling or re-skilling necessitated by technological development to avoid job displacement, which is certainly relevant, but from the less established angle of supporting the development of these skills through digital technologies, namely AI. AI can help companies solve these problems by, for example, enabling them to personalise employee career development and training programmes (Zel and Kongar, 2020) or to nurture employees' social and soft skills (Aviv *et al.*, 2021; Nambiar *et al.*, 2017).

Nevertheless, a comprehensive review of AI in personal development research has not yet been conducted. Comprehensiveness implies a special perspective on the topic pursued by this paper, because it refers to the role of AI in all stages of the employee journey, *from cradle to grave*, not limiting its scope to the classic employee lifecycle (like in Nosratabadi *et al.*, 2022) but integrating upstream the experience accumulated by the individual during, for example, university studies, before entering the workforce. This is a gap that needs to be addressed for several reasons.

Firstly, this body of research has been growing rapidly, and the introduction of AI into organisations has sufficiently challenged traditional HRM to warrant research investigation (Bankins, 2021; Stone *et al.*, 2015; Vrontis *et al.*, 2022).

Secondly, this body of research seems fragmented as it is spread across different applications, such as virtual working environment applications (Rahimi *et al.*, 2022) and HR analytics implications (Jiang and Akdere, 2021), or domains such as education (Wollny *et al.*, 2021) and the employee lifecycle (Nosratabadi *et al.*, 2022).

Thirdly, as suggested by Li *et al.* (2023), research needs to focus on the impact of AI at a micro level in organisations.

To address the extant gaps, this study reviewed the literature on AI in HRD from the viewpoint of personal development to answer the following two research questions:

RQ1: *How does artificial intelligence fit into the employee journey in support of their professional and personal development?*

RQ2: *What thematic strands and avenues of knowledge and research are most advocated in academic literature on management and beyond?*

To answer these questions, we analysed 151 papers published from 2002 to 2022. A literature review combined with bibliometric techniques (Donthu *et al.*, 2021; Mukherjee *et al.*, 2022) was applied. Following Mariani *et al.* (2023), we deployed content analysis to illustrate the most recurring topics and research streams, as well as the most promising theoretical, institutional, and practical implications stemming from the literature.

This study contributes to HRD literature in several ways.

Firstly, there is a pressing need to examine new and more effective approaches to HRD (Whysall *et al.*, 2019). Accordingly, the structure of the paper encompasses a range of topics that cluster into five main groups: i) AI in HR and contextual factors; ii) AI in education and future skills; iii) AI Coaching with chatbots; iv) AI in HR recruitment and training; and v) AI in soft skills development.

Secondly, this paper highlights the need for technological investment in personal development regarding both the educational and the organisational spheres. In analysing the literature under such lenses, we adopted a cross-contamination perspective that enriches both domains under the umbrella of AI for the personal development of the individual, whether a student (who will eventually transition into the workforce) or an employee. This can help researchers navigate between these different perspectives.

Thirdly, most of the literature reviews on AI in this domain have taken a qualitative approach (Budhwar *et al.*, 2022; Ravid *et al.*, 2020). In contrast, in the present research we combined the systematic (qualitative) and bibliometric (quantitative) literature review methodologies, thus striving for a comprehensive review approach that encapsulates the strengths of both paradigms. The remainder of the paper is structured into three sections. The next section explores the method and tools used for our research. The following section presents the bibliometric analysis results. Finally, we discuss the investigation and conclude by indicating the managerial implications, limitations, and future avenues of research.

2. Methodology

Inspired by Li *et al.* (2023) and Mariani *et al.* (2023), we deemed it appropriate to adopt a systematic quantitative literature review approach (Tranfield *et al.*, 2003) driven by bibliometric analysis. Bibliometric analysis tends to be more objective and extensive in scope than other types of review (Fan *et al.*, 2022); in combination with a systematic review approach, it allows scholars to provide a "*comprehensive coverage of the literature on the research topic*" (Li *et al.*, 2023, p. 3).

2.1 Search strategy

The primary data source used for this study is Elsevier's Scopus database, typically considered one of the most complete in the business and management discipline (Zupic and Čater, 2015). We employed a search query that involved the title, abstract and keyword fields to identify pertinent and related research (Crossan and Apaydin, 2010; Pisani *et al.*, 2017), using the following search query:

TITLE-ABS-KEY (AI OR "artificial intelligence" OR "intelligent agent" OR "human-agent interaction*" OR "robot-human interaction*" OR "intelligent automation" OR "machine learning" OR "deep learning" OR "neural network*" OR chatbot* OR "AI coach*" OR "AI tutor*" OR "AI mentor*")*
AND
TITLE-ABS-KEY ("human resource develop*" OR "human capital develop*" OR "human resource* improv*" OR "human capital improv*" OR "human capital train*"OR "human resource* train*" OR "human resource* coach*" OR "human capital* coach*" OR "HRD" OR "coaching" OR "personal develop*" OR "soft* skill*" OR "general skill*" OR "life* skill*")*
AND
(PUBYEAR > 1999)
AND
LANGUAGE (ENGLISH)
AND
LIMIT-TO (DOCTYPE, "cp")
OR
LIMIT-TO (DOCTYPE, "ar")
OR
LIMIT-TO (DOCTYPE, "cr")
OR
LIMIT-TO (DOCTYPE, "ch")
OR
LIMIT-TO (DOCTYPE, "re")
OR
LIMIT-TO (DOCTYPE, "bk")

The selection of search terms was informed by Vrontis *et al.* (2022), and two sets of keywords were searched in various combinations using the 'advanced search' function. The first set of keywords consisted of words that

belong to or are related to the AI, machine learning and chatbot domains. The second set of keywords contained words that are relevant to the HR, HRM, coaching and personal development domains. Given the specific perspective pursued by this paper on AI as a support for the development of soft skills and not as a cause of de-skilling, it was deemed appropriate to restrict the research in this regard. When relevant and appropriate, words were searched in both singular and plural forms and contracted and extended forms using the asterisk.

The purpose of such a wide range of keywords was to ensure that the collection of literature was as broad and inclusive as possible. For this reason, we considered all the subject areas of Scopus and the most common types of academic work (articles, conference papers, reviews, books, and book chapters).

2.2 Literature Selection

To identify the articles to include in our review, we conducted a multistep comprehensive search (Haddaway *et al.*, 2022). The overall process is illustrated in Figure 1. The preliminary phase of selection involved screening the titles and abstracts of the resulting records: only those deemed relevant were assessed for eligibility with full-text analysis. This was done in order to skim off non-relevant works at the source-for example, works that cited AI as a buzzword-and at the same time, avoid analysing papers resulting from linguistic ambiguity. As an example of the latter, in the fields of medical and environmental sciences, the acronym HRD represents vastly different concepts compared to HR research, such as homologous recombination deficiency, hyper reflective dots, high-risk drinking, high-resolution density, and high recommended dose. As a result, these works were excluded from this bibliometric literature review.

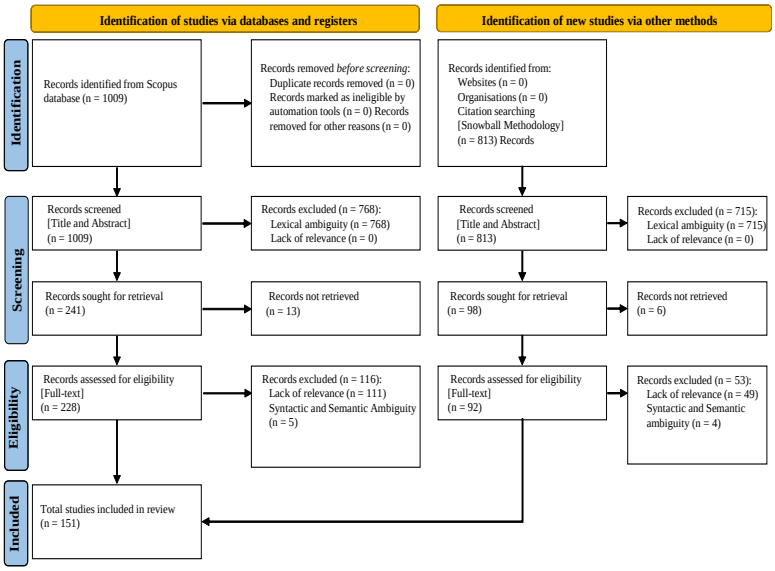
A further selection effort was undertaken to address semantic ambiguity: for example, contributions were excluded in which the word 'development' is related to a totally different meaning from that intended in the present study (e.g. 'software development' in Iftikhar *et al.*, 2021). This preliminary phase of the selection process was crucial, serving to exclude studies that were deemed irrelevant and thus limiting the full-text analysis solely to those studies that demonstrated pertinence to our literature review. During the full-text analysis, several articles were excluded due to lack of relevance, as in van Oorschot *et al.* (2018), because they pursued a different scope, focus or perspective with respect to the present analysis. For example, Man (2020) addressed the topic of HRD from a macro perspective, which sees HRD as a strategic asset for a country's growth, expressing a strictly complementary view to that of the present work, which is instead micro, being more focused on the companies.

Based on the outcome of the first full-text analysis, it was deemed appropriate to expand the scope of exploration through the snowball methodology, utilising Wohlin (2014) as a reference, and thus following both forward and backward snowball approaches. The forward snowball approach selected for evaluation the 300 most relevant papers citing the contributions contained in the sample resulting from the first full-text

analysis; the backward snowball approach selected the 513 most relevant contributions from the reference lists of the papers contained in the sample just mentioned. It seemed appropriate in this case to adopt the relevance criterion pre-determined by Scopus (Elsevier, 2023), considering that it should select papers by similarity instead of simply choosing the most cited, which could hardly have been the most relevant in a niche topic such as the one under investigation in the present work. The corpus of scientific output resulting from the snowball approach was then subject to the same inclusion and exclusion criteria applied to the works resulting from the database search.

The flowchart for the dataset acquisition is shown in Figure 1.

Fig. 1: PRISMA flowchart



Source: Our own elaboration.

2.3 Bibliometric analyses

The final sample of papers (151) was analysed using a similarity visualisation programme (VOSviewer) to showcase some of the results visually. VOSviewer is a professional software designed to visualise intellectual structure (van Eck and Waltman, 2010), and the methods employed are used in the science mapping literature. The analyses and visual representation are of significant importance as they may aid academics and practitioners in comprehending the areas that have been studied more effectively in these types of topic.

The focal analyses performed using VOSviewer were keyword co-occurrence analysis (KCA) and bibliographic coupling analysis (BCA).

KCA is a preliminary thematic analysis and aims to construct a keyword co-occurrence network (KCN), which has been demonstrated to

be useful in exploring the relationship between research topics in various scientific fields. Indeed, as noted by Radhakrishnan *et al.* (2017, p. 2), multiple studies "*have demonstrated the practical value and advantages of KCN-based analysis over traditional literature review approaches*". KCA is suitable for preliminary research work which aims to guide future research efforts by providing "*a knowledge map and insights prior to conducting a rigorous traditional systematic review*" (Radhakrishnan *et al.*, 2017, p. 1). This was accomplished by examining the relationship between keywords (both author and index keywords were selected), using a full counting method. The threshold for the minimum number of occurrences of a single keyword was set to two; two keywords were considered to co-occur if they both appeared in the same title, abstract, or citation context. Furthermore, since the distance between two keywords in a KCN is approximately inversely proportional to their co-occurrence similarity, the clustering function in VOSviewer groups together keywords that frequently co-occur in the sample of publications. This allows a visual representation of the relationships between keywords and an understanding of how they are connected. In other words, the clustering is based on the similarity (relatedness) of the keywords, keywords that have a higher rate of co-occurrence being placed closer together (Bornmann *et al.*, 2018; Waltman *et al.*, 2010). Since this type of analysis "*assumes that words that frequently appear together have a thematic relationship with one another*" (Donthu *et al.*, 2021, p. 289), the results of the KCA were essential to make adequate a priori sense of the results of the subsequent BCA to lead the reasoning and discussion about the actual content of every paper in each cluster from a common thematic foundation.

In contrast, BCA is designed to analyse the intellectual structure of the subject. First introduced by Kessler (1963), bibliographic coupling seeks to identify links between publications that jointly cite another publication. Kessler proposed that bibliographic coupling can be utilised to indicate which papers should be read by whom (Weinberg, 1974) and has five main characteristics: i) it is independent of language and words; ii) no expert judgement is required; iii) it encompasses both the past and the future; iv) it does not produce a static classification for a given paper as the groupings are subject to change based on changes in literature usage; and v) papers that share a unit of coupling with a given paper can be considered its logical references. In contrast to other techniques such as co-citation analysis, bibliographic coupling is forward-looking, as it tends to prioritise younger research and is useful in detecting the connections among research groups. It is also deemed more appropriate for studying emergent literature fields (Liu, 2017). The relatedness of documents in bibliographic coupling is established through the number of shared references. In this method, 'N' documents are considered coupled when they possess 'n' common references, where 'n' is a minimum of one. The connection between these documents is based on the overlap of their reference lists. The greater the number of shared references between two publications, the stronger the relationship between them.

3. Results

3.1 General statistics

The sample of the study consisted of a total of 151 publications by 160 authors affiliated with 160 institutions in 51 countries; they were published in 75 different sources and referred to 2,156 cited references (Table 1). Database interrogation results were updated as of 23 December 2022.

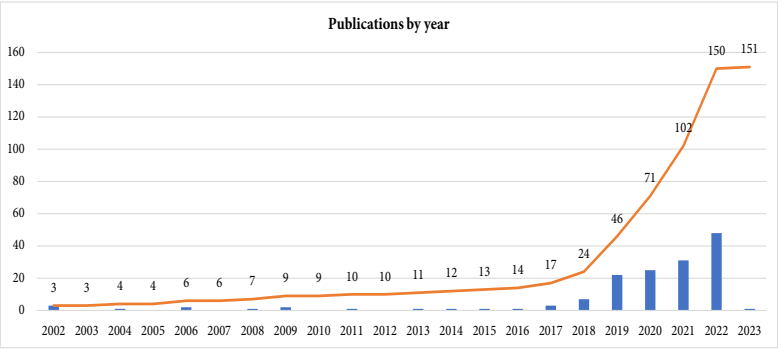
Tab. 1: Descriptive statistics of resulting publications

Statistics of selected sample of papers	
Publications	151
Authors	160
Journals	75
Institutions	160
Countries	51
Cited references	2,156

Source: Our own elaboration on extraction process data.

Figure 2 shows the distribution of publications in our sample by year; it suggests that the scientific field under observation is still in its infancy. The graph shows that publications have more than tripled in three years, from 46 in 2019 to 150 in 2022.

Fig. 2: Publications distribution in the sample by year



Source: Our own elaboration on Scopus data.

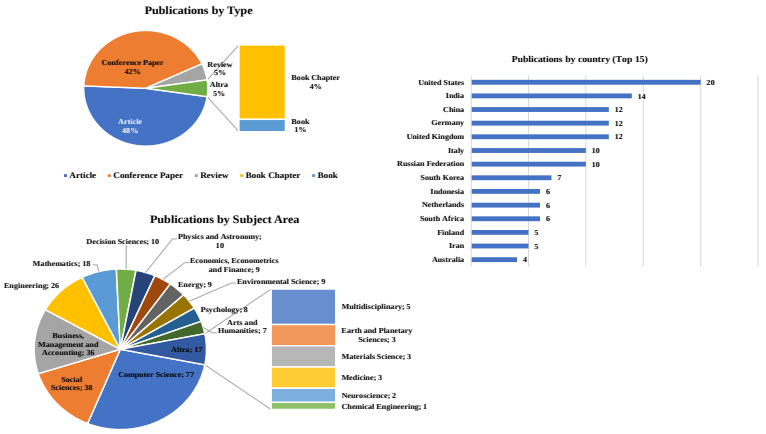
Figure 3 shows the distribution of publications by type, subject area, and country.

The extreme novelty of the field under investigation motivates the consistent presence of conference papers in the sample, since conferences offer swifter publishing mechanisms than journals and are more suitable to discuss novel topics and future scenarios among peer scholars. The significant diversity of contributions in terms of subject area reflects the remarkably cross-cutting nature of AI as a general purpose technology

(GPT) (Bekar *et al.*, 2017), encompassing even very diverse branches of knowledge.

An analysis of the distribution by country shows the dominance of the United States of America with 20 papers, followed by India, China, Germany, and the United Kingdom as the next most prolific countries. However, interest in the field is globally quite widespread, as our sample is populated by authors from 51 countries around the world (Table 1).

Fig. 3: Publication distribution by type, subject area, and country



Source: Our own elaboration on Scopus data.

Tables 2, 3, and 4, respectively, show the most prolific authors, sources and institutions of the papers taken into consideration in the review.

The significant presence of conference papers is confirmed, as three of the top five sources are collections of proceedings. This is undoubtedly due to the aforementioned swifter publishing mechanisms peculiar to conferences, which favour the publication of papers in research streams that are not yet fully established, such as the one investigated.

A fair distribution of scientific production is noted, considering that the top five authors, sources, and institutions in terms of the prolificacy of contributions represent, in the most significant case (top five sources), less than 20 per cent of the total sample. This result symbolises a certain degree of plurality in the scientific landscape focusing on AI in personal and HR development processes.

Tab. 2: Most prolific authors (Top 5)

Most Prolific Authors (Top 5)	Papers
Terblanche, N.	5
Molyn, J.	3
Graßmann, C.	2
Härting, R.C.	2
Jayagopi, D.B.	2

Source: Our own elaboration on Scopus data.

Tab. 3: Most prolific sources (Top 5)

Most Prolific Sources (Top 5)	Papers
Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	9
International Journal of Manpower	5
Journal of Physics Conference Series	5
Sustainability Switzerland	5
ACM International Conference Proceeding Series	4

Source: Our own elaboration on Scopus data.

Tab. 4: Most prolific institutions (Top 5)

Most Prolific Institutions (Top 5)	Papers
University of Stellenbosch Business School	4
Vrije Universiteit Amsterdam	3
Oxford Brookes University	3
University of Southern California	3
Texas State University	3

Source: Our own elaboration on Scopus data.

Table 5 shows the most cited sources sorted by number of global citations, while Table 6 presents the most relevant publications in the sample under investigation sorted by normalised citations. Apart from Sivathanu and Pillai's (2018) review paper, the most influential contributions are all recent contributions which, despite their young age and the limited scope of the field, have already accumulated a significant number of citations. This is further evidence of the vibrancy that has characterised research in this area in recent years.

Tab. 5: Most cited sources (Top 5)

Most Cited Sources (Top 5)	Citations
IEEE Intelligent Systems	870
Sustainability (Switzerland)	199
Human Resource Management International Digest	135
Proceedings of the National Conference on Artificial Intelligence	88
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	75

Source: Our own elaboration on Scopus data.

Tab. 6: Most influential publications sorted by normalised citations (Top 5)

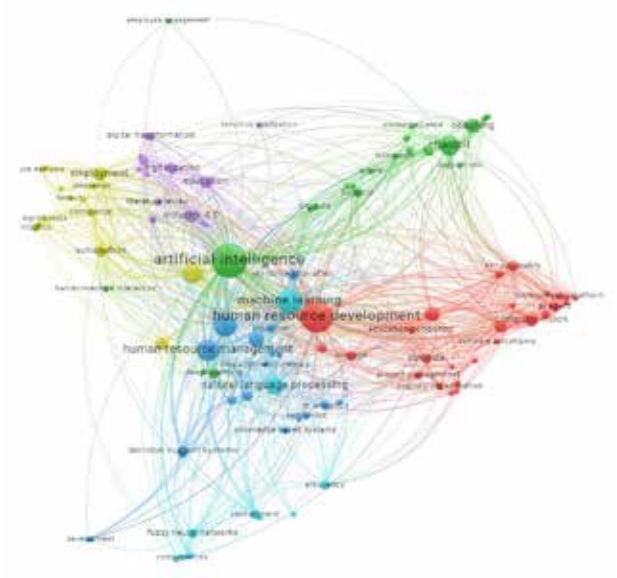
Most influential Publications by normalised citations (Top 5)	Authors	Year	Journal	Citations	Norm. Cit.	Source Type
Impact of artificial intelligence on employees working in industry 4.0 led organizations	Malik N.; Tripathi S.N.; Kar A.K.; Gupta S.	2022	International Journal of Manpower	15	17.14	Article
Influences of the industry 4.0 revolution on the human capital development and consumer behavior	Sima V.; Gheorghe I.G.; Subić J.; Nancu D.	2020	Sustainability (Switzerland)	126	12.91	Article
A study of artificial intelligence on employee performance and work engagement: the moderating role of change leadership	Wijayati D.T.; Rahman Z.; Fahrullah A.; Rahman M.F.W.; Arifah I.D.C.; Kautsar A.	2022	International Journal of Manpower	5	5.71	Article
Smart hr 4.0 - how industry 4.0 is disrupting hr	Sivathanu B.; Pillai R.	2018	Human Resource Management International Digest	135	5.37	Review
Employees' perceptions of the implementation of robotics, artificial intelligence, and automation (raia) on job satisfaction, job security, and employability	Bhargava A.; Bester M.; Bolton L.	2021	Journal of Technology in Behavioral Science	22	4.80	Article

Source: Our own elaboration on Scopus data.

3.2 Keyword Co-occurrence Analysis

The KCN generated by VOSviewer, with the minimum number of each grouping set to ten, consists of 113 keywords interconnected by 1,005 links with a total link strength of 1,623. The visualisation of the network, shown in Figure 4, highlights the presence of six distinct thematic clusters which exhibit some degree of imbalance in terms of their size: at the ends of the spectrum, cluster 1 collects 26 keywords and cluster 6 hosts only 12.

Fig. 4: Keyword co-occurrence network



Source: VOSviewer

Tables 7a to 7f illustrate the keywords contained in each of the six thematic clusters. The number of occurrences of each keyword within the entire sample of papers is displayed, as well as their average seniority, expressed by the weighted average of each keyword occurrence's corresponding year. The frequency of keyword occurrences provides insight into the dominant themes addressed in the reviewed literature, while the average seniority helps visualize the temporal trends present within each thematic strand.

Tab. 7a: KCN cluster 1 (red) keywords list

Keyword	Cluster	Occurrences	Avg. Year
human resource development	1	56	2018
Students	1	12	2020
e-learning	1	8	2013
computer vision	1	8	2014
virtual reality	1	6	2015
AI agent	1	5	2007
classification (of information)	1	5	2020
Curricula	1	5	2020
Surveys	1	5	2020
multi agent systems	1	4	2004
Teaching	1	4	2015
project management	1	4	2017
education computing	1	4	2020
technological platform	1	3	2008
engineering education	1	3	2020
distance learning environment	1	2	2002
technological resources	1	2	2002
software prototyping	1	2	2006
intelligent vehicle highway systems	1	2	2009
virtual humans	1	2	2011
Architecture	1	2	2012
professional aspects	1	2	2014
information use	1	2	2019
professional competencies	1	2	2020
Learning	1	2	2021
Extraction	1	2	2022

Source: Our own elaboration on VOSviewer export data.

Tab. 7b: KCN cluster 2 (green) keywords list

Keyword	Cluster	Occurrences	Avg. Year
artificial intelligence	2	66	2019
Chatbot	2	22	2019
Coaching	2	12	2021
deep learning	2	6	2021
health care	2	4	2019
Humans	2	4	2022
human computer interaction	2	3	2018
big data	2	3	2020
goal attainment	2	3	2022
support tool	2	2	2018
mental health	2	2	2019
Brain	2	2	2020
Competences	2	2	2021
Reflection	2	2	2021
employee engagement	2	2	2021
Motivation	2	2	2021
self-disclosure	2	2	2021
working alliance	2	2	2021
digital storage	2	2	2022
human-machine interaction	2	2	2022
learn+	2	2	2022
Article	2	2	2022
systematic literature review	2	2	2022

Source: Our own elaboration on VOSviewer export data.

Tab. 7c: KCN cluster 3 (blue) keywords list

Keyword	Cluster	Occurrences	Avg. Year
human resources	3	28	2020
human resource management	3	26	2019
neural networks	3	12	20196
decision makers	3	6	2017
decision support systems	3	6	2020
resource allocation	3	5	2021
Managers	3	4	2019
Algorithm	3	4	2017
HR analytics	3	3	2021
Semantics	3	3	2015
knowledge based systems	3	3	2019
employee performance	3	2	2021
Development	3	2	2009
Ontology	3	2	2012
evaluation modelling	3	2	2014
simple multiattribute rating technique (smart)	3	2	2019
image analysis	3	2	2020
long short-term memory	3	2	2020
software design	3	2	2021
Current	3	2	2021
Organisational	3	2	2021

Source: Our own elaboration on VOSviewer export data.

Tab. 7d: KCN cluster 4 (yellow) keywords list

Keyword	Cluster	Occurrences	Avg. Year
soft skills	4	22	2019
Employment	4	11	2021
information management	4	9	2020
Automation	4	8	2021
Commerce	4	4	2019
Robotics	4	3	2020
digital skills	4	2	2019
Innovation	4	2	2019
labor market	4	2	2020
R&D	4	2	2020
Fintech	4	2	2020
skill analysis	4	2	2020
digital economy	4	2	2021
job analysis	4	2	2021
job satisfaction	4	2	2021
support vector machines	4	2	2021

Source: Our own elaboration on VOSviewer export data.

Tab. 7e: KCN cluster 5 (violet) keywords list

Keyword	Cluster	Occurrences	Avg. Year
Industry 4.0	5	11	2020
Education	5	9	2020
Digitalization	5	7	2021
Management	5	5	2017
digital transformation	5	4	2021
data mining	5	3	2019
literature review	5	3	2021
Leadership	5	3	2021
resource management	5	2	2020
higher education	5	2	2020
case study	5	2	2021
South Korea	5	2	2021
strategic approach	5	2	2021
Sustainability	5	2	2021
sensitive application	5	2	2021

Source: Our own elaboration on VOSviewer export data.

Tab. 7f: KCN cluster 6 (light blue) keywords list

Keyword	Cluster	Occurrences	Avg. Year
machine learning	6	33	2020
natural language processing	6	17	2021
fuzzy neural networks	6	5	2016
Recruitment	6	5	2021
Efficiency	6	4	2021
knowledge management	6	2	2016
Competencies	6	2	2016
social networking (online)	6	2	2021
knowledge workers	6	2	2021
lifelong learning	6	2	2021
process automation	6	2	2022
Productivity	6	2	2022

Source: Our own elaboration on VOSviewer export data.

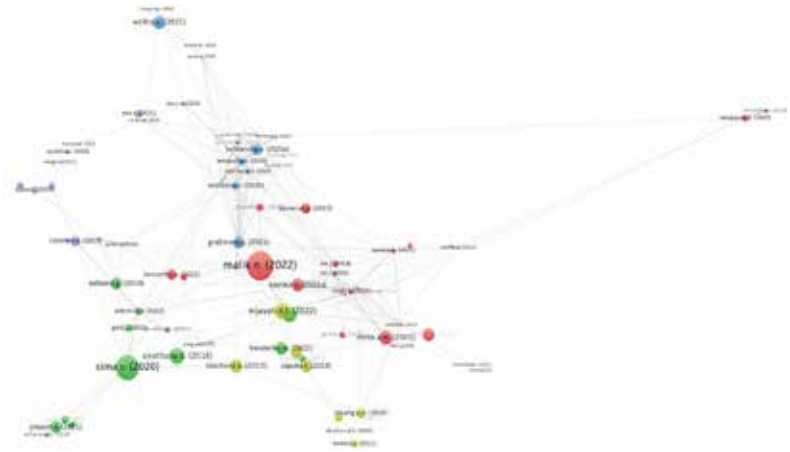
As stated earlier, preliminary results provided by KCA in terms of topics enriched the understanding of thematic clusters resulting from the BCA, described below.

3.3 Bibliographic Coupling Analysis

The bibliographic coupling network (BCN) generated by VOSviewer, the minimum number of each grouping set to ten, consists of 92 (out of 151) papers interconnected by 274 links with a total link strength of 466. The visualisation of the network, as shown in Figure 5, highlights the presence of five distinct bibliographic clusters which exhibit some degree of imbalance in terms of their size: at the ends of the spectrum, cluster 1 collects 31 papers and cluster 5 hosts only 11. The network nodes have been weighted by normalised citations: in this way, the larger ones also represent the most relevant contributions in relation to their seniority. From a brief visual overview of the network, it is apparent that clusters are mostly well-segmented from each other, apart from cluster 2 and cluster 4, which present a discrete overlapping in terms of inter-cluster proximity, meaning that those neighbouring contributions share a fair number of references even though they belong to different clusters. Cluster 3, on the other hand, appears incredibly specialised thematically, and of all the clusters in the BCN presents the highest degree of internal consistency. Such an excellent result could be related to the compactness of the reference literature that specifically insists on AI Coaching and its recency (in terms of mean publication year) compared to the other clusters and the full sample of papers. Intra-cluster distance is in most cases quite small; hence, we can expect a fair amount of coherence between neighbouring papers pertaining to the same cluster. There are some peripheral sub-clusters, however, which exhibit a large intra-cluster distance, strikingly represented by Muralidhar *et al.* (2018) and Nambiar *et al.* (2017) and to a lesser extent by Kuhail *et al.* (2022) and Wollny *et al.* (2021) and Fareri *et al.* (2021), Poquet and de Laat (2021) and Williamson *et al.* (2018). From these contributions, we can

expect less intra-cluster and even less inter-cluster coherence, since they are linked with very few other contributions, either internal or external to their cluster. Fifty-nine contributions out of the total 151 populating the sample under review were not clustered by VOSviewer: this is because they apparently share no reference either with those 92 included in the Figure 5 network or with each other. This testifies to the extreme interdisciplinary nature of scientific research effort on AI, even in a niche area such as the one investigated. Likewise, this attests to the extreme vibrancy of the field, given that many of the contributions in the sample rest on unshared and not yet consolidated literature.

Fig. 5: Bibliographic coupling network



Source: VOSviewer

4. Discussion

4.1 Keyword Co-occurrence Analysis

Cluster 1 (red; AI in students' skills development) largely shows topics concerning students and AI systems to support the development of students' skills, including professional skills. The papers that insist on these themes are mostly institution-oriented in nature. For example, Odrekhivskyy *et al.* (2019) propose a novel approach to the building of intellectual virtual learning environments (IVLE) in the university education system, towards the transformation of the *student learning* journey from a "*teacher-student system into a teacher-IVLE-student system*" (Odrekhivskyy *et al.*, 2019, p. 4). In those systems, AI is embedded in a virtual learning platform and acts as an expert tutor supporting the learning process and evaluating its outcomes, the teacher assuming a more creative role, making final decisions, and managing the double-ended interaction process. Another interesting example is that of Johnson *et al.* (2019), who propose an intelligent tutoring system in the form of a chatbot embedded in an online platform fuelled by

an AI agent that trains and evaluates students' negotiation skills and tactics. The authors show that students interacting with those intelligent agents "*improve in their use of both value-claiming tactics through a combination of practice and personalized feedback*" (Johnson *et al.*, 2019, p. 125).

Cluster 2 (green; AI Coaching with chatbots) addresses the multifaceted theme of coaching with intelligent systems and agents like AI chatbots, with reference to studies that devote such tools to both students (Mai *et al.*, 2021; Terblanche *et al.*, 2022c), and workers and managers (Graßmann and Schermuly, 2021; Schermuly *et al.*, 2021). The former perspective is represented by, for example, Mai *et al.* (2021), who, testing the interaction between a chatbot and university students on exam anxiety, offer useful insights on how the chatbot's disclosure of information about the topic leads to an increase in interaction, self-disclosure and rapport by the user. The authors conclude , in line with other contributions (Justice *et al.*, 2020; Vysotskaya *et al.*, 2020; Yorks *et al.*, 2020), that interaction with a chatbot stimulates users' personal reflection, which is seen as a goal in coaching (Kanatouri, 2020). Such an orientation is usefully synthesised by Graßmann and Schermuly (2021), who offer innovative insights into the use of AI in HRD processes in firms and how it can be used in coaching as a key tool. The authors provide a conceptual systematisation of AI Coaching, defining it as "*a machine-assisted, systematic process to help clients set professional goals and construct solutions to efficiently achieve them*" (Graßmann and Schermuly, 2021, p. 109). The authors argue that AI Coaching systems can learn from large databases of human-to-human coaching processes and become more efficient in helping clients achieve their goals, and they have the advantage of adaptability to the user with whom they interact. However, the study also points out that it is unlikely that AI will completely replace human coaches, and that human coaches are essential at the beginning of the coaching process as AI cannot understand clients' underlying needs and goals.

Cluster 3 (blue; AI and HR analytics) refers to a small number of contributions proposing the implementation of AI-fuelled decision support systems to improve HR allocation, evaluate employee performance and augment HR analytics. An illustration of the application of AI in HR analytics can be seen in the study conducted by Salvetti *et al.* (2022). The authors collaborated with an Italian insurance company to develop a training project that leverages HR analytics and AI. The HR analytics helped to gather valuable information, such as the organisational climate, performance metrics, and the key competencies and skills of each employee. This information was used to design a learning and development plan, which was implemented using an online learning platform featuring mixed-reality simulations enabled by virtual reality (VR) and AI technologies. Another example in this vein is that of Solichin and Hana Saputri (2021), who proposed a method to improve HR allocation through the use of artificial neural networks: based on several HR metrics, their system was able to provide recommendations to the managers of an Indonesian manufacturing company regarding the transfer of employees to other branches, thereby enhancing the efficiency and effectiveness of HR decision-making processes. Another study that stressed this issue

is addressed by Sihombing and colleagues (2019), who implemented a decision support system to assist HRD managers in selection of the best employee in a more effective and efficient way, overcoming the limitations of human biases and bounded rationality.

Cluster 4 (yellow; AI and future skills development) represents the broad themes of soft skills, future skills, and employment scenarios in a deeply and more than ever digitised workplace environment and society in general. For example, De Villiers (2021) proposed a model that can be used by business schools to ensure that graduates can fully contribute to a society impacted by automation and AI by entering the workplace with the requisite skills: the author identifies seven guiding principles to aid educators in the preparation of accounting students for the changes (and challenges) brought by automation and AI. Another example of AI-enabled skills training tools is provided by Rodriguez-Ruiz *et al.* (2021), who implemented natural language processing (NLP) tools based on AI to develop and especially assess students' digital literacy skills. The authors show that use of the proposed NLP tools in the skills assessment phase helps to "*avoid interpretation biases on the part of the teacher and provoke a perception of trust on the part of the students*" (Rodriguez-Ruiz *et al.*, 2021, p. 7), enhancing perception of the validity and reliability of those assessment instruments. A similar tool was proposed by Johnson *et al.* (2020), by followed a novel approach to the teaching of software engineering to Computer Science undergraduate students, based on machine learning (ML) and other digital technologies. The authors demonstrate that using this approach enhances students' career readiness by "*improving preparedness in students for computing job interviews*" (Johnson *et al.*, 2020, p. 10).

Cluster 5 (violet; Industry 4.0 and contextual factors) appears to be at the nexus between cluster 1 and cluster 4: this should not be surprising, since all literature reviews in the sample (Gkinko and Elbanna, 2022; Härting *et al.*, 2021; Kuhail *et al.*, 2022; Nosratabadi *et al.*, 2022; Rahimi *et al.*, 2022; Sima *et al.*, 2020; Sivathanu and Pillai, 2018; Wollny *et al.*, 2021) can be traced back to this cluster. This cluster encompasses a mixture of broad themes treated in other clusters, no contribution apart from reviews pertaining exclusively to it.

Cluster 6 (light blue; Fuzzy logic in HR recruitment and training) refers to a discrete number of contributions in the sample that address the selection and training of human resources with the support of AI systems based on fuzzy logic. For example da Silva *et al.* (2020) leverage the fuzzy sets theory to analyse the HR data of two companies in the electricity sector in Brazil: their model was able to understand the main aspects that must be improved to develop human capital in a more reliable way by reducing the subjectivity due to human evaluation. Since human capital stands as "*one of the main factors of competitive advantage*" (da Silva *et al.*, 2020, p. 5) of companies, this study fuels the belief that the implementation of AI systems in those HR processes effectively yields a competitive advantage. Another technical contribution to this topic is that by Maddumage *et al.* (2019), who proposed an intelligent recruitment system based on NLP techniques supported by a fuzzy inference system. In

particular, their system demonstrated effectiveness in resolving ambiguous scenarios where human evaluators face difficulty making decisions, such as when two candidates receive the same score. The implementation of fuzzy logic in such situations helps to clarify and make a final decision. Similar results are presented by Fachrizal *et al.* (2019), whose e-recruitment system is made to speed up the recruitment process and support HR decisions, and by Michalopoulos *et al.* (2022), with the quantification and prediction of employees' skills and productivity that provides granular metrics for each employee, enabling a more effective employee ranking process. An additional contribution is made by Zhou and colleagues (2022): their method is not limited to the evaluation of candidates' performance, but also provides constructive criticism or suggestions for employees in professional and personal improvement, pushing the AI intervention towards actual HRD.

4.2 Bibliographic Coupling Analysis

Cluster 1 (red; AI in HR and contextual factors) is the most crowded of the five clusters and appears as a large scientific cauldron populated with loosely coupled papers. Although they all deal with the themes of AI in HR in the context of Fourth Industrial Revolution (4IR), there are contributions (Jatobá *et al.*, 2019; Mishra *et al.*, 2021; Nosratabadi *et al.*, 2022; Votto *et al.*, 2021; Xin *et al.*, 2022) that address those themes with a broad perspective on all HR processes encompassing all phases of the employee lifecycle. For the purposes of the present paper, it is useful to highlight, for instance, the findings of Votto and colleagues (2021), who state that AI has the potential to make HR processes more efficient in organisations by providing customised training recommendations based on employees' strengths, interests, and potential for success. Digital training assistants, like AI-based chatbots, can store experienced employees' best practices and monitor performance; they do not possess the in-depth knowledge that experienced workers have, however, and are therefore unable to replace HR trainers completely. In addition, by utilising AI-based VR simulations for mandatory employee training, companies can improve participation, boost efficiency, and lower the costs of training initiatives. These AI-enhanced training tools should be used to supplement employee development, human input providing a personalised touch to employees' onboarding process. Organisations can therefore create smarter learning platforms to improve performance and cultivate talented, innovative, and diverse employees. In this scenario, AI tools must be designed and geared to interact with employees and foster their growth within the company.

Other contributions (Aviv *et al.*, 2021; Muralidhar *et al.*, 2018; Nambiar *et al.*, 2017; Rasipuram and Jayagopi, 2020) focus on AI-based soft skills assessment and training in the workplace. These works mainly highlight the benefits for job candidates and employees deriving from the interaction with AI-based virtual agents, mainly in the form of intelligent chatbots, which enable them to receive automatic and personalised feedback to improve their social and soft skills. Several other studies (Bennett and McWhorter, 2022; Rahimi *et al.*, 2022) further elaborate on the implications of AI in the

virtual training of employees by investigating the transformation of virtual workplace environments and digital employee experience related to AI. For example, digital automation frees up HR teams' time, allowing them to focus on building stronger relationships with employees, managers, and job candidates to better meet their needs (Zel and Kongar, 2020).

Cluster 2 (green; AI in education and future skills) insists on the influence of new technologies on personal development from an educational perspective, and the implications in terms of skills needed for the workplace of the future. In this vein, Sima *et al.* (2020) state that the 4IR exerts a significant influence on human capital development, changing the way work and employment are conducted and the required skills of employees. The rise of automation and robotisation is leading to job losses in repetitive, routine sectors, mainly affecting lower-educated workers. As a result, workers need to acquire new skills to cope with the transformations in production processes and attain greater job satisfaction and security (Bhargava *et al.*, 2021). Digitalisation is affecting the entire economic and social environment, requiring a new set of skills for emerging types of work, and impacting higher education. Labour markets are experiencing a lack of ICT professionals, with a shortage in the advanced manufacturing sector where big data and cybersecurity skills are needed (Sima *et al.*, 2020). To cope with these changes, the authors recommend a combined effort from government, schools and universities, trainers, and companies to adapt curricula and increase the IT skills and innovation skills of the workforce. 4IR, indeed, requires education systems that focus on knowledge beyond what is currently taught and the stimulation of creativity from an early age (Sivathanu and Pillai, 2018). The educational perspective on 4IR is also pursued by Williams (2019), who stresses, for instance, the importance of universities leveraging AI-enabled learning analytics, pre-emptively identifying students at risk of failure and tailoring tutoring initiatives for them. Poquet and de Laat (2021) then address the topic of learning analytics from the broader perspective of lifelong learning, emphasising the opportunity to shift the purpose of learning from human capital to human development, with the focus on capabilities, envisioning "AI-based technologies as a partner in cognition" (Poquet and de Laat 2021, p. 1703).

Cluster 3 (blue; AI Coaching with chatbots) appears incredibly specialised, thematically speaking, focusing on coaching implemented with AI-based chatbots, and presents the highest degree of internal consistency. The contributions in this cluster also appear to be the most coherent and functional for the purposes of this paper. Indeed, this cluster exhibits a dual soul, which in a holistic review paper on AI, encompassing the entire employee journey *from cradle to grave*, is worth emphasising: although the majority of contributions envision AI Coaching in workplace scenarios, some influential papers, like that by Wollny *et al.* (2021), explore AI Coaching activities with intelligent chatbots in the educational context, shaping it in the form of AI tutoring and mentoring. According to Wollny *et al.* (2021), the primary objectives of the implementation of AI-based chatbots in the education sector can be summarised in four categories: i) skills improvement; ii) efficiency of education; iii) enhancement of student motivation; and iv) availability of education. The authors also identify three

different pedagogical roles assignable to AI chatbots in education: learning, assisting, and mentoring. Chatbots can support learning in various ways, such as through integration into the curriculum as a learning aid or through additional offerings outside the classroom. One example of this is a chatbot simulating a virtual pen pal that helps students practise language skills. Chatbots can also assist students by simplifying their daily tasks, such as providing information or automating processes. Additionally, chatbots can serve as mentors to students, focusing on their personal development and encouraging reflection on and assessment of their progress. Other contributions in cluster 3 related to the educational domain (Kuhail *et al.*, 2022; Mai *et al.*, 2021; Terblanche *et al.*, 2022c) are quite consistent in results with Wollny *et al.* (2021), producing pretty similar categorisations and taxonomies for AI tutors and mentors in terms of objectives and roles. Kuhail and colleagues (2022) highlight several limitations of these systems that are worth noting, however: inadequate dataset training, lack of user-centred design, loss of interest over time, lack of feedback, and distractions.

Shifting the focus from the educational to the workplace and professional context, the research by Graßmann and Schermuly (2021) is by far the most prominent, representative and influential paper in cluster 3. The authors present a pioneering examination of the utilisation of AI in HRD and its potential as a crucial tool for coaching. They formulate a systematic framework for AI Coaching, characterising it as a "*machine-assisted, systematic process to help clients set professional goals and construct solutions to efficiently achieve them*" (Graßmann and Schermuly, 2021, p. 109). The authors contend that AI Coaching systems have the capability to acquire knowledge from extensive databases of human-to-human coaching sessions and, as a result, become more proficient in helping clients attain their objectives. The authors assert that AI Coaching chatbot systems have the potential to assist users effectively in navigating various stages of the coaching journey and building strong working alliances. Additionally, these systems can adapt to the unique needs of each user. Nonetheless, the study highlights that complete substitution of human coaches by AI is improbable: human coaches play a vital role in the initial stages of the coaching process as AI is not yet fully capable of comprehending the underlying needs and goals of users if they are implicit or not clearly communicated. According to Graßmann and Schermuly (2021), the use of AI in coaching holds the promise of revolutionising the coaching industry, presenting a cost-effective solution that can reach a wider range of users. As a result, AI Coaching has the potential to become a valuable tool in the field of HRD (Terblanche, 2020), democratising coaching processes in an effective and efficient way, as confirmed by Terblanche *et al.* (2022a). There are three factors that influence the adoption of AI Coaching chatbots: performance expectancy, facilitating conditions, and social influence (Terblanche and Kidd, 2022). In addition, the use of chatbots as coaches provides the benefit of anonymous interaction, particularly in situations in which sensitive information may be disclosed (Terblanche, 2020).

Terblanche *et al.* (2022b) provide further optimistic results on AI Coaching performance and efficacy. Their study involved a comparison between human coaches and an AI chatbot coach. The results showed that

both types of coach were effective in helping users reach their goals, and the AI coach was as effective as human coaches by the end of the trials. This discovery has significant implications, as it suggests that AI Coaching could scale coaching services and potentially grow demand for human coaches, while also potentially replacing human coaches with simplistic, model-based methods. At present, however, as also stated in Graßmann and Schermuly (2021), AI lacks empathy and emotional intelligence, which renders human coaches not completely replaceable.

Finally, Ellis-Brush (2021) presents less enthusiastic results than those in Graßmann and Schermuly (2021), finding that although an AI agent can deliver positive outcomes through a conversational coaching process (e.g. with an improvement in self-resilience), a working alliance between the coachee and the AI coach has not been developed.

Cluster 4 (yellow; AI in HR recruitment and training) exhibits a strong overlap with cluster 2. Stachová *et al.* (2019), for example, draw similar conclusions to those of Sima *et al.* (2020) from their analysis of the challenges and trends of personal development and education in the 4IR scenario. Indeed, the authors confirm the view that "Industry 4.0, and in particular automation that interferes with multiple processes and professions, gradually changes employee education and skills requirements" (Stachová *et al.*, 2019, p. 13). This idea is also supported by Caputo *et al.* (2019) with regard to firms' investment in Big Data and by Wijayati *et al.* (2022), with regard to AI in the workplace.

Perhaps the most relevant contribution in cluster 4 from a managerial perspective is that of Maity (2019), who proposes a model to identify future trends of AI in HR training and development processes. According to the author, the use of AI in knowledge management and employee training and development is becoming increasingly important for organisations. To stay competitive, companies need robust knowledge management practices that are easily accessible to all employees. AI is also playing a crucial role in shifting training and development from classroom-based programmes to personalised, intuitive and adaptive mobile learning experiences. AI has the potential to identify individual learners' characteristics and design training programmes tailored to those characteristics, which is crucial for meeting the current need for individualised training programmes. From a technical point of view, this cluster hosts different contributions to solve the issues of personnel selection and competence improvement (Chuang *et al.*, 2020; da Silva *et al.*, 2020; Michalopoulos *et al.*, 2022; Zhou *et al.*, 2022), to propose to employees alternative training scenarios (Kantola *et al.*, 2011), and to evaluate the success of training initiatives (Kalinouskaya, 2022).

Cluster 5 (violet; AI in soft skills development) is in a sense complementary to cluster 2, in that, again in the common context of 4IR, while the authors included in cluster 2 refer mainly to hard skills (e.g. ICT and data analysis skills), most of the contributions in cluster 5 deal with AI and the assessment and development of soft skills. Although several contributions focus on the educational field, other papers in this cluster appear to be more market-oriented and anchored to the organisational reality of companies. Colombo *et al.* (2019), for example, find that soft and

digital skills tend to moderate the job displacement effects of automation technologies even in highly automatable sectors, complementing the use of machines and software and "*making the job less substitutable*" (Colombo *et al.*, 2019, p. 35). Of an entirely different nature is the work by Sayfullina *et al.* (2018), who propose several approaches based on a neural network model to match the soft skills required by job postings and those present in candidates' CVs. Their proposal offers an effective solution for firms looking to automate the initial phase of candidate evaluation, as the model can effectively disambiguate the soft skills matching process and reduce false positives significantly. This work provides an innovative solution for HR departments looking to streamline their recruitment process and make more informed decisions based on the skills and characteristics of potential candidates. Likewise, the work by Wings *et al.* (2021) presents a practitioner-oriented nature and is aimed at the automatic classification and extraction of hard and, especially, soft skills from candidates' CVs. It starts from the same technical assumptions but achieves a broader purpose than the study by Chang *et al.* (2022), who, leveraging NLP and ML techniques, develop a skills extraction algorithm that can be used to analyse students' skills, university course syllabi and online job postings. By analysing different data sources, the authors provide an initial landscape of skill needs for specific job titles and conduct a within-sector analysis based on programming jobs, the computer science curriculum, and undergraduate students. They find that students have a range of hard and soft skills, but they may not be the ones desired by employers. Additionally, they observe a discrepancy between the skills taught in university courses and those in demand by industry, with a lack of emphasis on soft skills. These findings highlight the importance of aligning university curriculums with the needs of industry to ensure that students are well prepared for their future careers (Kosarava, 2021). The contributions of Pasikowska *et al.* (2013) and Schutt *et al.* (2017) are in line with the development of more practitioner-oriented AI tools and models. These authors propose chatbots and virtual environments enriched by AI techniques directed respectively to patients with mental health issues and health professionals in training.

Table 8 summarises the themes investigated by the authors in each cluster, draws out the major takeaways, and outlines the trajectories that future research should pursue in each thematic strand.

Tab. 8: Major takeaways and future RQs

Cluster	Themes	Major takeaway	Future RQs
Cluster 1	• AI enables improved efficiency of HR processes. • AI can learn best practices from experienced employees. • AI can identify current employees who are most likely to succeed and those who most need support. • AI can inform human decision-makers on HRD strategies.	AI as a partner, not a rival – AI-augmented strategy & decision-making	• What guidelines are needed for the ethical development and implementation of AI systems in the context of HRD? • What are potential users' and companies' perception of AI-augmented HRD processes? • What are the challenges of integrating AI into strategy and decision-making processes within HRD, and how can they be overcome? Is it possible to identify best practices for companies adopting such systems?
Cluster 2	• AI and other digital technologies change labour scenarios and employee skills requirements. • Technological unemployment mainly affects medium-low educated workers. • AI-enabled learning analytics can identify students at risk of failure and tailor tutoring measures. • AI pushes towards the shift from human capital development to personal development of current and future employees.	AI-enabled future skills prediction	• What are the future-proof skills whose development can best be supported by AI? • How does the introduction of AI systems, particularly large language models, into business processes impact the competencies of intellectual and high-skilled workers? Does it enhance or destroy their competencies?
Cluster 3	In education scenarios, AI Coaching assumes three pedagogical roles (teacher, assistant, mentor) and: • Enables skills improvement. • Improves efficiency and availability of education. • Enhances study motivation. In the workplace context, AI acts as goal setter and solution finder in all stages of coaching journey, providing: • A cost-effective coaching solution for companies. • The democratisation of business coaching activities, by reaching a wider audience. • A safe space for reflection, in which sensitive information and emotions can be disclosed by the employee without fear of judgement or repercussions on his/her career	AI Coaching for everyone	• What are the main characteristics that render AI Coaching systems attractive to both students and employees? • What is the role of trust in the acceptance dynamics of AI Coaching systems? Are trust antecedents different between students and employees? • Can modern large language models compensate for the lack of empathy and emotional intelligence of AI Coaching systems reported in the existing literature?
Cluster 4	• AI systems are formidable cost-effective solutions for recruiting and on-boarding processes, but their role is not limited to this. • The development of AI and other digital technologies does not just change the skill sets required of employees but influences the processes of knowledge creation and management. • HRD processes are shifting from one-to-many classroom activities to one-to-one personalised learning experiences supported by AI.	AI in the whole employee lifecycle	• How can AI contribute to the establishment of more robust knowledge management practices? • How can AI be utilised to evaluate the success of training initiatives?
Cluster 5	• AI systems are able to evaluate and train students and employees' soft skills in both educational and workplace contexts. • Soft skills tend to moderate the job displacement effect of automation technologies. • There is a lack of emphasis on soft skills in university courses, even though these are in high demand on the labour market	AI-enabled soft skills education	• How can AI be utilised to identify and bridge the gap in soft skills between university education and labour market demands? • What is students' attitude towards and perception of AI supporting soft skills improvement? • How will educational programmes change with the introduction of AI—for example, in the field of entrepreneurship education?

Source: Our own elaboration.

5. Conclusion

The rapid integration and advancement of AI in various sectors, including economics and management, has ushered in a wealth of both promise and challenges for personal and human resource development.

Although the academic discourse on AI in the economics and management fields is often related to the percentage of traditional jobs that risk being displaced by AI (Acemoglu and Restrepo, 2020; Jackson and Kanik, 2019; Ray and Mookherjee, 2022), it is equally important to stress the benefits of AI in HRD and, more broadly, in HRM.

AI's transformative potential extends to various HRM processes such as recruitment, performance evaluation and employee training. It offers data-driven insights, personalised feedback, and cost-effective solutions, enabling HR professionals to make more impartial decisions and providing

valuable insights into employees' behaviour and preferences. However, the ascent of AI also casts a spotlight on ethical and social considerations, encompassing issues like data privacy, algorithmic bias, job displacement, and technostress.

The implications of integrating AI into the domain of personal and human resource development are manifold, and the shift to the new HR 4.0 paradigm presents both opportunities and challenges for organisations and society as a whole. Beyond its immediate impacts, AI introduces a profound shift in skills requirements and expectations of the contemporary and future workforce. As we confront the demands of 4IR, individuals must adapt, acquiring new competences and skills, namely soft skills.

The ethical challenges associated with the development of AI, which have been posed with increasing insistence in the literature (Bankins, 2021; Gkinko and Elbanna, 2022; Wirtz and Mueller, 2019), seem to be linked increasingly to the concepts of trust and risk. Supranational regulatory bodies such as the European Parliament have recently drawn up guidelines (AI Act, European Parliament, 2023) to ensure the human-centric development of AI, classifying AI systems based on their degree of risk in relation to fundamental rights, among which the right to privacy stands out.

Ultimately, everything seems to be pressing with conviction in the direction of AI development driven by human needs and not simply by technological advancement. Thus, a balanced and well-informed evaluation of the benefits and limitations of AI implementation in HRM is crucial to ensure its responsible and ethical deployment. This underscores the crucial call for a human-centric and ethical approach to AI development and implementation within the realm of personal development and HRD.

5.1 Theoretical and Institutional Implications

Based on the findings of our comprehensive literature review, we offer three theoretical and institutional implications for advancing further research on AI in the HRD literature.

Firstly, our findings enable researchers to understand the scope of research in this field and how these domains can be evaluated from a cross-fertilisation perspective. Researchers may use our results to explain the adoption of AI in HRD using other literature, such as that from the educational domain. The theoretical framework depicted in Figure 6 stems from this perspective. The figure provides an integrated view of major takeaways descending from the several thematic strands populating this multifaceted field of research, bridging them with critical actors at play and new trajectories for future research efforts.

Secondly, our findings provide researchers with critical information on prestigious and influential articles that may be seen as the foundations of this research field. New gaps that need to be filled are related to i) education policy and how these factors can influence social, economic, and educational outcomes; ii) labour dynamics regarding the investigation of the mechanisms of adoption, acceptance, and trust in the educational and employment contexts; and iii) identification of the key components that

should be included in the initial conversation to build trust between the client and the chatbot coach.

Thirdly, our findings highlight ethical issues about the impact of AI on society-wide social sorting and the potential amplification of discrimination and negative effects in the workplace. The impacts of AI adoption include information security, data privacy, drastic changes resulting from digital transformations, and job risk and insecurity. Technostress creators among employees include work overload, job insecurity and complexity (Malik *et al.*, 2022). Consequently, a new ethical framework is needed to guide the application of AI in the HRD area. This study calls for policymakers and professionals engaged in the legal and information technology domains to examine these factors.

5.2 Practical Implications

This study's findings may also be of practical interest to companies. Based on the results, we offer three practical implications for managers to facilitate the implementation and adoption of AI in HRD.

Firstly, practitioners may utilise our research to understand the broad scope of AI's applicability in HRM processes and operations across diverse sectors and managerial domains (Lee *et al.*, 2021; Schermuly *et al.*, 2021).

Secondly, these practitioners may apply the findings of prestigious studies to discuss the design choices and trade-offs that may address major hindrances in AI's implementation in HRD. For example, further investigation is required to determine the optimal balance between human-like features and transparency about limitations. Factors that need consideration are: i) the user's personality type; ii) the level of humanness and anthropomorphic behaviour displayed by the chatbot; iii) the appropriate use of user input and predefined options; iv) the setting of realistic expectations through the initial conversation; and v) the role of various other factors in technology adoption (e.g. trust).

Thirdly, the findings imply the need to investigate practically the role of universities in adopting AI in educational programmes to facilitate students' transition to the workforce.

5.3 Insights and Future Lines of Research

Drawing insights from a comprehensive literature review on AI in personal development and HRD, our exploration has yielded six major takeaways descending from the overarching themes pursued by the clusters identified with BCA. These weave together the current state and future trajectory of this interdisciplinary field, like logically linked building blocks. These blocks revolve around the aforementioned cross-fertilisation view, which does not hinder the role of AI in supporting HRD in terms of time and space by confining its action to the workplace, but rather enhances it to the point of embracing the entire employee journey, from cradle to grave, as depicted in Figure 6.

The first block, AI as a partner, not a rival, underscores the need for a collaborative and complementary relationship between humans and AI

systems. Rejecting competitive dynamics, AI should be viewed as a tool that supports and augments human capabilities, necessitating further exploration into ethical and legal guidelines for its development and use, alongside a better understanding of user perceptions and acceptance mechanisms.

Moving seamlessly to AI-enabled future skills prediction, we delve into the proactive role of AI in forecasting and identifying optimal skill sets for future workers. This involves aligning educational curricula with market demands, prompting research into collaboration between academic institutions and businesses and best practices for integrating AI into educational systems. In this view, an enhanced degree of collaboration and synergy between academic institutions and the business sector is imperative. Joint future research endeavours could indeed utilise AI systems to forecast the optimal skill set required for future workers, thereby facilitating the redesign of educational curricula.

Building on this, the third block, AI-enabled soft skills education, accentuates the significance of soft skills (e.g. communication, creativity, problem-solving, and teamwork) in the 4IR scenario. AI, serving as an enabler, assists in the assessment and improvement of these skills through interactive and personalised learning experiences. Future research is crucial to understanding users' attitudes and motivations and overcoming challenges in implementing AI for soft skills development.

The fourth block, AI in the whole employee lifecycle, builds on the outcomes of the previous ones, harvesting their fruits. In this vein, extant literature recognises the broad applicability of AI across diverse HRM processes in various sectors. Future research should delve into the optimisation of recruitment, onboarding, performance evaluation, employee training, and coaching through AI by exploring best practices and trade-offs and reaping an understanding of the impact of AI on the overall employee experience.

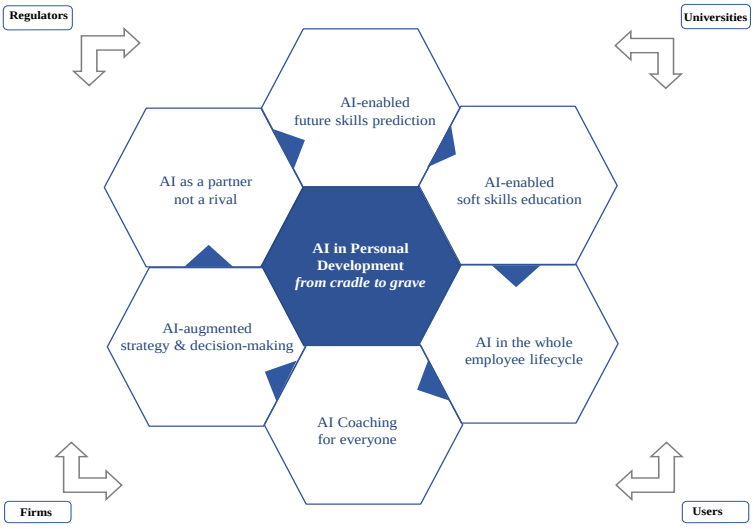
As acknowledged in the literature, business coaching is a crucial process for HRD, such that it deserves a separate block in our framework. AI Coaching for everyone unveils AI's potential to democratise and scale coaching services. By reaching a wider and more diverse audience, AI provides a secure and anonymous space for reflection and feedback, representing cost-effective solutions to support employees' psycho-physical wellbeing. Future research endeavours should empirically validate the effectiveness of such systems and delve into understanding the role of trust and other factors in the acceptance and adoption of AI Coaching.

The sixth block, AI-augmented strategy & decision-making, binds again to the first, like a Ouroboros, by addressing the strategic implications of widespread AI use in HRM and beyond. This encompasses effects on business strategy and decision-making processes, where AI informs and supports human decision-makers by providing data-driven insights, predictions, and recommendations. Future research in this domain should explore the challenges, opportunities, and best practices for integrating AI into strategic decision-making processes.

Collectively, these intertwined themes construct a comprehensive and cohesive framework, shedding light on the intricate web of AI in personal

development and HRD, including, last but not least, the actors at play (firms, users, regulators, universities), which interact at various levels with each other and with the aforementioned technology building blocks in a synergistic manner.

Fig. 6: AI in personal development - from cradle to grave



Source: Our own elaboration.

5.4 Limitations

The present review has certain limitations that should be considered.

Firstly, the scope of the study was limited to articles published in the Scopus database, which is one of the largest sources of published articles but may still exclude relevant studies that were published in other databases such as Web of Science or Google Scholar.

Secondly, the preliminary search was also limited to scientific documents written in English and excluded other languages. This may reduce the generalisability of the results. Future research may consider including other languages to provide a more comprehensive understanding of the field.

Thirdly, 39 per cent of the full sample of papers was not included by VOSviewer in the BCN network depicted in Figure 5. Because of this, and limited to the analysis of the BCA results, this paper may have provided a partial view of the landscape of the literature concerned with AI in personal and human resource development. In this regard, however, it is important to mention the safeguards put in place by the authors: first of all, the BCA is greatly strengthened by the preliminary thematic analysis (KCA) based on the keywords of the entire sample of papers (including those missing the full text and those not included in the BCN), which provided broad overarching themes that were largely reflected in and confirmed by the analysis of BCA results. Secondly, a manual cross-check

of the contributions not included in the BCN was carried out to make sure that no contribution relevant to the emerging scientific debate was missed.

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sinergie
italian journal of management

ISSN 0393-5108
ISSN 2785-549X
DOI 10.7433/s123.2024.06
pp. 121-163

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Appendix

Authors	Title	Year	Source title	DOI	Link
Kambur E., Yildirim T.	From traditional to smart human resources management	2023	International Journal of Manpower	10.1108/IJM-10-2021-0622	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85138364523&doi=10.1108%2fIJM-10-2021-0622&partnerID=40&md5=64c087a3251ee21a7c17c7dfde8ac96b
Pikkarainen A., Tihinen M.	Education as a Promoter of Digital Transformation in the Manufacturing Industry	2023	Lecture Notes in Networks and Systems	10.1007/978-3-031-16598-6_8	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85142417247&doi=10.1007%2f978-3-031-16598-6_8&partnerID=40&md5=8330daef6e8bd11d7790d582e5efce65
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Terblanche N., Molyn J., Williams K., Maritz J.	Performance matters: students' perceptions of Artificial Intelligence Coach adoption factors	2023	Coaching	10.1080/17521882.2022.2094278	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85133237360&doi=10.1080%2f17521882.2022.2094278&partnerID=40&md5=cd365ad8e498a1e4c474b891ba26581f
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Feng D., Gao Y.	A HRD evaluation method based on BP neural network	2009	2nd International Symposium on Information Science and Engineering, ISISE 2009	10.1109/ISISE.2009.55	https://www.scopus.com/inward/record.uri?eid=2-s2.0-77952664312&doi=10.1109%2fISISE.2009.55&partnerID=40&md5=fcd8392f07269441f0fc5c7dff27a3a9
Fang X., Qi T.	Human resource development by fuzzy neural networks	2008	2008 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2008	10.1109/WiCom.2008.1723	https://www.scopus.com/inward/record.uri?eid=2-s2.0-58049112688&doi=10.1109%2fWiCom.2008.1723&partnerID=40&md5=4756e8a307f6bd8156a3da30c7d90124
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Garro A., Palopoli L., Ricca F.	Exploiting agents in e-learning and skills management context	2006	AI Communications		https://www.scopus.com/inward/record.uri?eid=2-s2.0-33744927912&partnerID=40&md5=12b7d744cc274c2f43273520522d3215f
Mohaghegh S., Razzazi M.R.	An ontology driven matchmaking process	2004	Intelligent Automation and Control Trends, Principles, and Applications - Proceedings of the Sixth Biannual World Automation Congress, WAC		https://www.scopus.com/inward/record.uri?eid=2-s2.0-32844462328&partnerID=40&md5=bed188dc8fdf821ae59cb6d4d077614bb
Mockler R.J., Adams J.F., Dologite D.G.	Nurturing professional growth through cognitive mapping: An Asian multinational manager's perspective	2002	Journal of East-West Business	10.1300/J097v08n01_03	https://www.scopus.com/inward/record.uri?eid=2-s2.0-0036413227&doi=10.1300%2fJ097v08n01_03&partnerID=40&md5=8fc94bc305dbbdbdb8b74a344038e6e7
Silveira R.A., Vicari R.M.	Developing distributed intelligent learning environment with JADE– Java agents for distance education framework	2002	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	10.1007/3-540-47987-2_15	https://www.scopus.com/inward/record.uri?eid=2-s2.0-84943269937&doi=10.1007%2f3-540-47987-2_15&partnerID=40&md5=ff591d35c54c075a54ecd3dcc6a2714e
Silveira R.A., Vicari R.M.	Improving interactivity in E-learning systems with Multi-Agent Architecture	2002	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	10.1007/3-540-47952-x_62	https://www.scopus.com/inward/record.uri?eid=2-s2.0-84874843916&doi=10.1007%2f3-540-47952-x_62&partnerID=40&md5=200ac07de97630364fae1d20adc251e7

From fields to bytes: orchestrating digital ecosystems in rural areas

Received
27th February 2023
Revised
1st June 2023
Accepted
31th January 2024

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Abstract

Framing of the research. *In recent years, agri-food companies have started to build digital platform ecosystems to implement complex value propositions. Typically orchestrated by a focal actor, these digital platform ecosystems have been seen as collaborative arrangements through which companies combine their individual offerings into a coherent customer-facing solution, the core of which is a technology platform. In contexts hostile to change, the role of orchestrators becomes even more critical for initiating and managing their construction.*

Purpose of the paper. *This study focuses on the emergence of digital platform ecosystems in rural areas and the key role of the orchestrator. Specifically, it aims to investigate how focal actors initiate their emergence in peripheral areas.*

Methodology*. We adopt a single case study design with a focus on an experimental initiative to create an integrated multichain digital traceability platform. To conduct the exploratory study, we draw on a series of primary and secondary data.*

Results*. Our results identify the set of activities through which a focal actor pursuing collective interests initiates the emergence of a digital platform ecosystem. By distinguishing between the ecosystem design and launch phases, we shed light on how the orchestrator plans not only the ecosystem but also the actions implemented to motivate participation and govern it.*

Research limitations. *This study is limited to companies operating against the backdrop of a shared project to create a digital platform ecosystem.*

Managerial implications. *Our study highlights how firms can manage the adoption of digital technologies by exploiting external collaborations. Moreover, we offer a multiplayer perspective of the mechanisms behind traditional sectors' innovative efforts in rural areas.*

Originality of the paper. *Although digital platform ecosystems have been the subject of numerous studies in the agri-food sector, to the best of our knowledge, there is no comprehensive and exhaustive exploration of the phenomenon within a rural area where ecosystem participants combine efforts to create value in an innovation-hostile environment.*

Key words: *digital platform ecosystems; rural areas; blockchain; agri-food*

1. Introduction

In recent years, agri-food companies have started to build digital platform ecosystems to implement complex value propositions (Gawer and

Cusumano, 2014; Jha *et al.*, 2016; Calabrese *et al.*, 2021). Along with this orientation, they have been regarded as collaborative arrangements through which companies combine their individual offerings into a coherent, customer-facing solution, the core of which is a technology platform and/or a set of shared resources, standards, and interfaces (Ceccagnoli *et al.*, 2012; Gawer, 2014). Value creation depends on complementary inputs from interconnected but hierarchically independent heterogeneous stakeholders, typically orchestrated by a focal actor capable of coordinating all participants and introducing a series of actions to shape the context in which they collaborate and compete (Thomas and Ritala, 2022).

While there is an increasing amount of research focused on established agri-food platform ecosystems (e.g., Tsolakis *et al.*, 2021), much less work addresses the creation of a de novo ecosystem within a rural area and the development of a shared structure of interactions. Moreover, establishing platform ecosystems-not an easy feat in itself-is particularly difficult in rural areas where geographical, cultural, and socioeconomic barriers can inhibit the adoption of emerging technologies (Rijswijk *et al.*, 2021; Schreieck *et al.*, 2021). In a context so hostile to change, the role of orchestrators becomes even more critical for initiating and managing the construction and collaboration of innovation networks, which represent valuable tools for connecting the countryside to the digital economy and achieving a more modern and sustainable future for the agri-food industry (Trendov *et al.*, 2019).

In response to the growing demand for contextualized studies on digital platform ecosystems (Gulati *et al.*, 2012; Jacobides *et al.*, 2018), this article directs its attention to their manifestation in rural areas, underscoring the critical role played by the orchestrator. The significance of exploring ecosystems' orchestration in rural settings lies in their unique dynamics, which offer valuable insights into the transformative impact of digital platforms on traditionally underserved regions. Specifically, adopting a single case study design (Eisenhardt, 1989) with a focus on a project that started in the Sicilian hinterland and drawing on a series of primary interviews and extensive secondary data, we address the following question: "*How do orchestrators initiate the emergence of digital platform ecosystems in rural areas?*". Our results identify the set of activities through which a focal actor defines strategies, mobilizes, and aligns with other actors and their resources while orchestrating the digital transformation of areas hostile to change. By distinguishing between the ecosystem *design* and *launch* phases, we shed light on how the orchestrator plans not only the ecosystem but also the actions implemented to motivate participation and govern it.

The remainder of this paper is organized as follows. Section 2 draws upon a conceptual framework on digital platform ecosystems, orchestrators, and their technology adoption process. Section 3 presents the methodology and research design. Section 4 briefly introduces the project's reference context and the characteristics of the companies involved. Section 5 presents the findings obtained by analysing orchestrator activity from a two-layered perspective. Section 6 provides theoretical and practical implications of the results. Finally, Section 7 highlights some limitations of the study.

2. Theoretical framework

2.1 Digital platform ecosystem

Digital platform ecosystems have quickly emerged as a promising stream of research in the entrepreneurship and innovation literature (Jacobides *et al.*, 2018). They have been broadly conceived as forms of endogenous strategic action where autonomous agents contribute to the digital platform's value proposition (Teece, 2018). Whereas traditional firms create value within the boundaries of a company or a supply chain, digital platform ecosystems drive coproduction, cocreation, and value capture (Hein *et al.*, 2020). They are built on collaborative arrangements between firms that combine individual offerings to create a coherent solution aimed at a defined audience and share a set of technical standards (Adner, 2006; Thomas and Autio, 2020). As the participants in the ecosystem depend on each other, offering a digital platform ecosystem requires careful orchestration of actors and resources. Even if most digital platforms act as private regulators of their ecosystems (Gawer, 2021), they facilitate transactions and innovation under the coordination and direction of the platform orchestrator (Wareham *et al.*, 2014, p. 1211). Orchestrators establish the rules through which their various actors interact, decide what behaviours to encourage or discourage on the platform, and choose how to enforce them (Autio, 2021).

In recent years, the digital platform phenomenon has attracted interest in the agri-food activities that have been reorganized around platform-based ecosystems for value creation and appropriation (Annosi *et al.*, 2020). Digital technologies, such as the Internet of Things (IoT) and blockchain, have been exploited to collect and record data to create efficient, transparent, and sustainable supply chains; more often, digital platform ecosystems have proven necessary for firms operating in the agri-food sector (Tsolakis *et al.*, 2021).

For example, adopting blockchain technology to record, store, validate, and secure data can solve various agricultural problems, such as business financing. Previous research has demonstrated that if banking and insurance industries are connected in real time to activity data in the farming industry, better credit ratings and profile models can be created (Rijanto, 2021). Additionally, in a context where consumers have become more educated at the bottom of supply chains and demand real-time updated information on foods they consume, digitalization has allowed the agri-food industry to be highly connected, efficient, and responsive to customer needs and regulatory requirements. The COVID-19 pandemic has also increased the reliance of individuals, businesses, and governments on online platforms. As a result, food product traceability, safety, and sustainability issues have become crucial concerns for food retailers, distributors, processors, and farmers. This situation has forced actors to accelerate the adoption of digital agriculture technologies to support emergency responses, making the issue especially topical and increasing institutional pressures that demand that actors participate in a traceability system (Hew, Wong, Tai, Ooi, and Lin, 2020). However, the rise and deployment of digital platform ecosystems

in the agricultural and food industries are challenging and resource demanding; they can prove particularly difficult within rural areas, where factors related to geographical, social, institutional, and market access conditions can act as barriers to environmental change and innovation (Baumber *et al.*, 2018, Miles and Morrison, 2020).

Despite the orchestrator's intervention, more conservative firms may not perceive this strategy favourably, holding them back from participating in the ecosystem and adopting digital technologies (Hew *et al.*, 2020). In this context, ecosystem leaders must persuade others to make voluntary inputs consistent with the ecosystem's overarching value offering. As such, in line with institutional theory (DiMaggio and Powell, 1983), which posits the influence of external institutions in driving isomorphism between firms (Yigitbasioglu, 2015), the orchestrator could exert pressure (coercive, mimetic, and regulatory) on firms, influencing their perceptions of digital systems (Hu *et al.*, 2016; Yigitbasioglu, 2015) and motivating their intentions to adopt (Teo *et al.*, 2003).

2.2 Orchestrating the emergence of a digital platform ecosystem

Research on the emergence of digital platform ecosystems has often focused on their structure, examining the actors involved and their linkages to establish a common value proposition (e.g., Özalp *et al.*, 2018; Rong *et al.*, 2015; Pan Fang *et al.*, 2021). Specifically, some studies have shed light on the role of the orchestrator, namely, the entity that provides key resources and infrastructure and regulates linkages between complementary actors to initiate the ecosystem and give it momentum (e.g., Autio, 2021; Mann *et al.*, 2022; Das and Dey, 2021).

Most of them identify as orchestrators with a focal firm operating in a highly innovative industrial setting, namely, a large, powerful, and established organization with the knowledge, resources, and key technologies to stimulate the emergence of an ecosystem and profit from it (e.g., Lingens *et al.*, 2022; Das and Dey, 2021; Hou *et al.*, 2020). In large rural settings, micro- and small enterprises attached to traditional values are often geographically isolated due to low entrepreneurial density and lack of infrastructure, and they lack the ability to stimulate the emergence of an ecosystem (Ferrari *et al.*, 2022; Hammer and Frimanslund, 2022). In these contexts, the ecosystem may be triggered by an external catalyst, namely, a third party with a strong relational position.

In contrast to focal firms, external orchestrators pursue collective interests-for example, social, environmental, or industry interests-and aim for network vitality to foster the diffusion of innovative ideas in highly uncertain environments (Hurmelinna-Laukkanen and Nätti, 2018). Moreover, in wide rural areas, these orchestrators may leverage public and private actors who are firmly rooted in the local microenvironment to legitimize the ecosystem and introduce it to potential complements, building a shared understanding of its purpose within the broader economic and social context (Thomas and Ritala, 2022; Lingens *et al.*, 2022; Rogers, 1961).

2.3 Orchestrating the participation in a digital platform ecosystem

The emergence of studies on digital platform ecosystems has encouraged researchers to scrutinize the decision-making processes that drive complementary autonomous agents to join a platform (Boudreau, 2010; Church and Gandal, 1992; Gawer and Henderson, 2007; Zhu and Iansiti, 2012). Most of the existing studies on how platforms attract complements often assume that they possess detailed information on the participants, the technologies involved in regulatory issues related to data governance, or the ecosystem's value proposition.

While this assumption may hold in regard to some established platform ecosystems, in emerging ecosystems, neither the set of platform actors nor the information regarding platform functioning or long-term sustainability may not be clear (Dattée *et al.*, 2018; Hannah and Eisenhardt, 2018; Pan Fang *et al.*, 2021). Moreover, in rural contexts, where average levels of education and skills are generally lower, fear of change and mistrust of technology disincentivize the adoption of emerging technologies and participation in a digital platform ecosystem (Ferrari *et al.*, 2022; Malecki, 2003; Salemink *et al.*, 2017). In scenarios of high uncertainty, the orchestrator plays a key role (Thomas and Ritala, 2022).

In fact, the orchestrator must have a clear "proto-vision" of the ecosystem and must convey this to potential complements to convince them to take part in overcoming critical mass and generating the indirect network effects typical of ecosystems (Datteé *et al.*, 2018; Katz and Shapiro, 1985; Rogers, 2003). Previous research has shown the importance of conferences and workshops being organized in an in-person format to attract possible users, introduce them to the platform and reduce perceived uncertainty about new technology (Dattée *et al.*, 2018; Garud, 2008; Özalp *et al.*, 2018; Pan Fang *et al.*, 2021). Specifically, the platform is proactively publicized in these meetings to stimulate awareness among potential users (Cusumano and Gawer, 2002; Rogers, 2003).

In this context, participants may influence each other, and early adopters may motivate adoption by sharing their experiences and taking a significant role in the education and training of potential users (Attewell, 1992; Bandura, 1986; Pan Fang *et al.*, 2021). Even in rural communities, in-person workshops appear to support the dissemination and adoption of digital technologies, contributing to peripheral areas' social and economic progress (Raisänen and Tuovinen, 2020). In this context, the orchestrator may leverage ecosystem partners that motivate entrepreneurs to attend conferences and training workshops through incentives (Pan Fang *et al.*, 2021). However, deploying a digital platform in contexts of high uncertainty is not immediate. Nevertheless, it recognizes time as a critical element of innovation. It requires iterative and recursive feedback loops-positive and negative-concerning the use of emerging technologies, which may lead to more or less homogeneous intersubjective convergence (Vargo, Archpru Akaka, and Wieland, 2020).

3. Methodology

We chose to employ a single case study design following the approach outlined by Eisenhardt (1989) to illuminate a digital platform ecosystem's emergence process in a rural context. The decision to utilize a single case study was grounded in the inherent advantages of the approach, which allows for a meticulous and comprehensive exploration of the phenomenon at hand. This design is suitable for testing theories within a specific context, dissecting an unusual situation worthy of detailed documentation, and conducting a longitudinal examination where conditions and underlying processes evolve (Yin, 2018). Therefore, the single case study design afforded us the depth and specificity necessary to uncover nuanced insights into the intricate dynamics of digital platform ecosystems in rural settings.

The present study was conducted on an experimental initiative sponsored by public and private actors to promote the territorial development of peripheral areas. The project aimed to create an integrated multichain traceability digital platform, enhance the UNI EN ISO 22005[1] certified Sicilian agri-food supply and promote the development of local economies. The designed system was based on the integration of various digital technologies-such as blockchain technology and the IoT-capable of recording information from the entire production process and ultimately making it accessible to the end consumer. The project involved a total of 194 enterprises-who voluntarily adhere to the initiative-located in the rural areas of Sicily (Figure 1). The participants included farms, processing firms, and packagers operating in eleven different supply chains, as detailed in Table 1.

Data collection began in February 2022 and ended in February 2023. To ensure the triangulation of the data and the robustness of our research results, the data collected were obtained from both primary (semistructured interviews) and secondary (desk analysis and information from the project kick-off meeting) sources (Benbasat *et al.*, 1987; Dubé and Paré, 2003; Eisenhardt, 1989; Yin, 2018).

Building on theoretical sampling (Glaser and Strauss, 1967), we conducted twenty-two semistructured interviews. We selected companies that produce differentiated agri-food products and operate at different supply chain stages among the available companies. In addition, we considered farms of various sizes. These choices lie in the possibility of highlighting variations between trials and identifying categories in terms of properties and dimensions (Strauss and Corbin, 1998). Thus, we involved nineteen company representatives. Furthermore, we interviewed the certification agency's project manager and two project promoters, namely, the project leader and a spokesperson, to help regional policy-makers better understand the initiative's goals and expected impact on local environmental development.

All the interviews were conducted in Italian, some on an online videoconferencing platform (MS Teams) and others over the phone. The

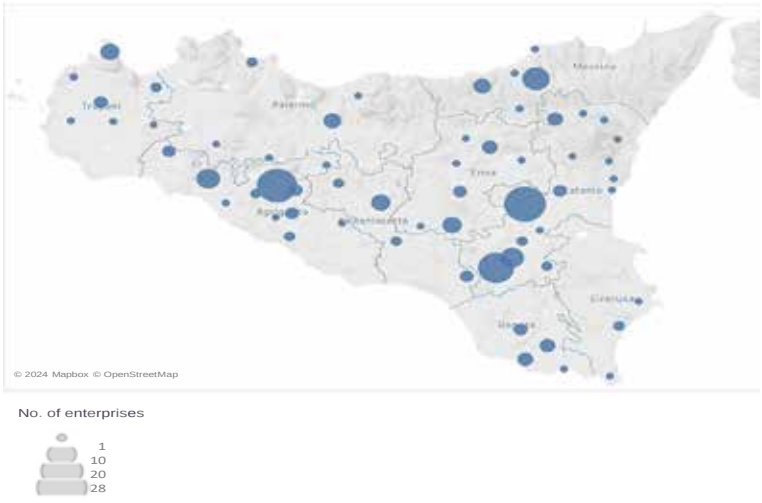
1 UNI EN ISO 22005:2008 is an international standard for the certification of agri-food traceability systems. Its objective is to support companies in documenting the history of the product, enabling its origin to be traced.

interviews lasted between 20 and 90 minutes each and were recorded, transcribed, and subsequently translated into English. At the beginning of each interview, we explained the study's objectives and ethical issues. We designed an interview outline consisting of eleven open-ended questions. The interview guide had two main sections of questions. The first section allowed informants to provide general considerations about their participation in the project and the role of the organizers. The second section explored how managers in the agri-food sector perceive digital transformation, highlighting the challenges and opportunities. Table 2 presents the twenty-two key informants, their job position, and the duration of the interviews. In addition, for the key informants of the nineteen companies, we indicated the type of company they work with and the supply chain in which the company operates.

We collected secondary data from archive documents (e.g., executive plan of project activities) and the official project website. In addition, we gathered information from the kick-off meeting held in February 2022. Table 3 shows a summary of the secondary data sources.

The data analysis used familiar approaches for inductive studies, and we had no a priori hypotheses. We read the cases independently to form our views of each actor's role in participating in the ecosystem. We began with detailed written accounts and schematic representations. We triangulated the primary data with secondary data, enriching the thematic analysis to the point of saturation (Strauss and Corbin, 1998). After constructing each profile, we conducted within-case analyses, which were the basis for developing early constructs surrounding ecosystem emergence as experienced by each actor. Cross-case analysis produced our working framework for ecosystem emergence and orchestration. The blended approach allowed us to remain open to surprises in the data while ensuring theoretical consistency from the outset. The results of the data analysis are presented and discussed in the following sections.

Fig. 1: Places and operators involved in the project



Source: Authors' elaboration on data from the executive plan of the project

Tab. 1. Number of companies operating in eleven different sectors

Supply chain	No. of companies
Extra Virgin Olive oil supply chain	62
Wheat and derivatives supply chain	55
Dried fruit and derivates products supply chain	28
Pulses, hemp, aromatic-officinal plants and their products and honey supply chain	23
Citrus fruit and citrus fruit products supply chain	19
Vegetables and their products supply chain	19
Livestock supply chain	12
Grape and grape products supply chain	10
Cheese supply chain	7
Prickly pear and prickly pear products supply chain	7
Exotic fruit and derivates products supply chain	5

Source: Authors' elaboration on data from the executive plan of the project

Tab. 2: Key informants

Key informant ID	Job position	Type of company and Supply chain	Interview duration (in minutes)
KI-1	Project Leader	/	90''
KI-2	Spokesperson for the regional policymakers	/	60''
KI-3	Certification agency's Project Manager	/	30''
KI-4	Sales Manager	Farm and Processor - Pulses, hemp, aromatic-officinal plants and their products and honey supply chain Livestock farms, processors, and packers - Livestock supply chain	20''
KI-5	Founder and Legal Representative	Farm and Processor - Cheese supply chain	25''
KI-6	Founder and Company Partner	Farm and Processor - Citrus fruit and citrus fruit products supply chain Processor and Packager - Wheat and derivates supply chain Farm - Extra virgin olive oil supply chain	40''
KI-7	Quality Manager	Processors and Packagers - Vegetables and their products supply chain	30''
KI-8	Quality Manager	Mill and Processor -Wheat and derivates supply chain	20''
KI-9	Founder	Farm - Citrus fruit and citrus fruit products supply chain Farm - Extra virgin olive oil supply chain	50''
KI-10	Owner and Legal Representative	Farm - Prickly pear and prickly pear products supply chain, Dried fruit and derivates products supply chain, Pulses, hemp, aromatic-officinal plants and their products and honey supply chain, Extra virgin olive oil supply chain, Vegetables and their products supply chain, Grape and grape products supply chain	60''
KI-11	Administrator	Mill and Processor -Wheat and derivates supply chain	20''
KI-12	Owner	Processor and packager - Citrus fruit and citrus fruit products supply chain, Cheese supply chain, Dried fruit and derivates products supply chain, Wheat and derivates supply chain	20''
KI-13	Administrator	Oil mill and packer - Extra virgin olive oil supply chain	40''
KI-14	Owner	Farm - Dried fruit and derivates products supply chain, Extra virgin olive oil supply chain, Wheat and derivates supply chain	35''
KI-15	Owner	Farm - Extra virgin olive oil supply chain	25''
KI-16	Owner	Farm - Wheat and derivates supply chain	30''
KI-17	Administrator	Farm, Processor and Packer - Vegetables and their products supply chain	40''
KI-18	Owner	Farm - Dried fruit and derivates products supply chain	55''
KI-19	Owner	Farm - Exotic fruit and derivates products supply chain	30''
KI-20	Owner	Farm - Extra virgin olive oil supply chain Farm and Processor - Grape and grape products supply chain	40''
KI-21	Owner	Processor and Packer - Wheat and derivates supply chain	40''
KI-22	Owner	Farm - Wheat and derivates supply chain	20''

Source: Authors' elaboration

Tab. 3: Summary of secondary data sources

Source	Type
Archive documents	Renewal of UNI EN ISO 22005:2008 certificate and start of digitization project Executive plan of project activities
Project kick-off meeting	Transcript of the kick-off meeting held on 14 February 2022
Official project website	Web Page

Source: Authors' elaboration

4. Reference context and general features of the project member enterprises

The project initiative is set in the rural areas of Sicily's nine provinces, comprising 96% of its 25,711 km2 surface area (ISTAT, 2010).

The richness of these territories in terms of biodiversity and quality of native crops clashes with the poverty of infrastructure and services that affects, above all, the region's innermost areas. In fact, they have a tangible and intangible infrastructure network-road and rail networks, broadband, telematic networks and logistics networks-that is extremely deficient. The absence of an extensive highway network forces the use of rural, often rutted roads, which affects the travel time of agri-food goods, particularly penalizing products meant for fresh consumption. In addition, due to their land morphology and low population density, many inland areas have low connectivity or no broadband at all. In these difficult contexts, the lack of essential services severely affects the quality of life of rural communities, fostering depopulation in hard-to-reach areas and hampering the potential for business creation and development.

The enterprises participating in the pilot project operate in eleven different supply chains, as detailed in Table 1. The distribution of participating enterprises shows a prevalence in the extra virgin olive oil and wheat sectors, which are traditional quality crops of the Sicilian hinterland. Finally, in terms of numbers, we find operators in the supply chain of exotic fruits and their derivative products. This is a booming market, especially in the Tyrrhenian strip of Messina (ME), which offers favourable environmental conditions for tropical fruit production.

General information on the participating firms, which is provided in Tables 4, 5 and 6, was acquired through the Orbis Bureau Van Dick database. Since 44 of the 194 participating enterprises are sole proprietorships-a type of enterprise not found in the database-the tables contain general information for 150 enterprises and financial and governance information for a variable and further reduced number of organizations. In more detail, Table 4 contains descriptive statistics for each supply chain and the entire group, while Table 5 details some information by sector. Finally, Table 6 provides some information on the management and supervisory bodies of the enterprises where available.

The enterprises participating in the initiative are micro- and small enterprises. In general, the size of these types of enterprises-which characterize the rural areas of inland Sicily-is responsible for excessive

fragmentation of the production fabric and poor vertical integration between production phases. Due to their small size, only 23 out of 150 enterprises-that is, 15.3%-have branches, and only 6 out of 150 enterprises-4%-have more than one branch. Excessive fragmentation of production makes it impossible to achieve economies of scale and reduce and optimize operating costs, causing many sectors to be unprofitable. Despite the presence of well-established enterprises-with an average age of 14 years-profits are limited, and in some cases, such as in the vegetable and prickly pear and derived products sectors, there are large losses.

Approximately 43% of the member enterprises-that is, 84 out of 194 companies-operate in two or more certified supply chains. The existence of multiproduct enterprises transcends the verticality of the supply chain and creates a complex cross-system-the so-called ecosystem-in which each organization must interact with operators in other supply chains.

Participating micro- and small businesses have a low rate of digitization; only 30% of them have already invested in digital technologies, i.e., by setting up a website. This figure suggests that digital transformation is proceeding very slowly and confirms the existence of a digital divide severely limiting peripheral areas' development. The highest percentage of businesses on the web belong to the supply chain of legumes, hemp, aromatic-officinal plants and derivatives, honey, and wheat and its derivatives.

A male presence at the top of the boards prevails over a female presence, but the latter seems to be gaining ground despite the cultural backwardness of the Sicilian hinterland. In fact, Table 6 shows that 70% of CEOs are men and 30% are women. There is also a female presence on other board roles and on the boards of auditors. Most of the governing and supervisory body members are between 25 and 49 years old, but there are numerous members who are older than 50 years. The presence of young people is still too limited, reflecting the reduced generational turnover that characterizes the Sicilian agribusiness sector, which is why the digitization process is not taking off.

The business strategy of the companies participating in the pilot project focuses on the high quality of niche regional agri-food products, which include raw materials and semifinished and finished products. In their efforts to bring down prices and be competitive in a market dominated by multinationals, their policy is to optimize production costs, particularly harvesting, which is normally done by mechanical means.

Tab. 4: Descriptive statistics

		Obs.	Mean	Std. Dev.	Min	Max
All companies	Web Presence	150	.333	.473	0	1
	Firm age	150	13.673	10.312	1	57
	Multi-chain	150	.407	.493	0	1
	Branches	150	.153	.362	0	1
	Multi-branches	150	.04	.197	0	1
	Sales and Services Revenues*	56	2.940.754	10.919.739	0	78.185.688
	Total Production*	73	2.515.856	10.582.472	0	86.870.563
	Net income*	56	37.041	187.26	-181.719	1.319.054
Extra Virgin Olive oil supply chain	Web Presence	62	.306	.465	0	1
	Firm age	62	10.742	7.769	1	29
	Multi-chain	62	.694	.465	0	1
	Branches	62	.177	.385	0	1
	Multi-branches	62	.065	.248	0	1
	Sales and Services Revenues*	28	1299.62	2847.59	.75	14.493.748
	Total Production*	32	1.295.399	2.581.682	12.95	13.398.802
	Net income*	28	64.245	254.199	-110.98	1.319.054
Wheat and derivates supply chain	Web Presence	55	.455	.503	0	1
	Firm age	55	14.764	9.821	2	47
	Multi-chain	55	.545	.503	0	1
	Branches	55	.109	.315	0	1
	Multi-branches	55	.036	.189	0	1
	Sales and Services Revenues*	19	1040.25	1680.72	0	5.665.908
	Total Production*	26	863.146	1.522.392	0	5.947.829
	Net income*	19	19.779	68.228	-61.511	248.847
Dried fruit and derivates products supply chain	Web Presence	28	.214	.418	0	1
	Firm age	28	9.143	6.895	1	25
	Multi-chain	28	.714	.46	0	1
	Branches	28	.107	.315	0	1
	Multi-branches	28	.036	.189	0	1
	Sales and Services Revenues*	14	7.091.454	20.807.255	13.708	78.185.688
	Total Production*	16	6.733.011	21.618.777	13.708	86.870.563
	Net income*	14	33.583	91.585	-110.98	279.955
Pulses, hemp, aromatic-officinal plants and their products and honey supply chain	Web Presence	23	.478	.511	0	1
	Firm age	23	14.913	9.811	3	39
	Multi-chain	23	.913	.288	0	1
	Branches	23	.217	.422	0	1
	Multi-branches	23	.043	.209	0	1
	Sales and Services Revenues*	9	1.072.818	1.798.284	6.328	5.665.908
	Total Production*	12	900.849	1657.08	8.896	5.947.829
	Net income*	9	16.236	47.987	-61.511	102.632
Citrus fruit and citrus fruit products supply chain	Web Presence	19	.316	.478	0	1
	Firm age	19	17.684	13.901	3	57
	Multi-chain	19	.737	.452	0	1
	Branches	19	.211	.419	0	1
	Multi-branches	19	.053	.229	0	1
	Sales and Services Revenues*	6	988.915	2.293.298	0	5.665.908
	Total Production*	9	760.974	1947.9	0	5.947.829
	Net income*	6	14.026	27.824	-3.201	67.043
Vegetables and their products supply chain	Web Presence	19	.421	.507	0	1
	Firm age	19	14.895	8.987	5	36
	Multi-chain	19	.526	.513	0	1
	Branches	19	.316	.478	0	1
	Multi-branches	19	.105	.315	0	1
	Sales and Services Revenues*	4	5.783.265	11.298.316	12.517	22.729.248
	Total Production*	7	3.548.613	8.883.736	83.066	23693.98
	Net income*	4	-44.462	93.313	-181.71	24.391
Livestock supply chain	Web Presence	12	.167	.389	0	1
	Firm age	12	17.083	11.658	3	39
	Multi-chain	12	.25	.452	0	1
	Branches	12	.167	.389	0	1
	Multi-branches	12	.083	.289	0	1
	Sales and Services Revenues*	3	5.188.657	8.061.642	309.088	14.493.748
	Total Production*	4	3676.56	6.487.324	175.667	13.398.802
	Net income*	3	103.794	154.032	-5.526	279.955
Grape and grape products supply chain	Web Presence	10	.4	.516	0	1
	Firm age	10	12.9	7.724	5	28
	Multi-chain	10	.8	.422	0	1
	Branches	10	.3	.483	0	1
	Multi-branches	10	0	0	0	0
	Sales and Services Revenues*	4	502.829	535.256	12.517	1.143.938
	Total Production*	4	565.099	531.018	113.222	1.173.705
	Net income*	4	16.164	12.907	3.042	29.746
Cheese supply chain	Web Presence	7	.429	.535	0	1
	Firm age	7	15.286	9.725	3	26
	Multi-chain	7	.429	.535	0	1
	Branches	7	.286	.488	0	1
	Multi-branches	7	.286	.488	0	1
	Sales and Services Revenues*	3	999.792	913.014	1.826	1.793.124
	Total Production*	4	843.743	860.461	3.529	1.820.117
	Net income*	3	31.565	60.916	-6.922	101.798
Prickly pear and prickly pear products supply chain	Web Presence	7	.286	.488	0	1
	Firm age	7	10.571	6.554	3	20
	Multi-chain	7	.429	.535	0	1
	Branches	7	0	0	0	0
	Multi-branches	7	0	0	0	0
	Sales and Services Revenues*	4	3068.46	4.864.798	.246	10.223.107
	Total Production*	4	3166	5.019.901	.264	10.548.795
	Net income*	4	-6.958	64.215	-90.866	65.583
Exotic fruit and derivates products supply chain	Web Presence	5	.2	.447	0	1
	Firm age	5	20	21.272	4	57
	Multi-chain	5	.6	.548	0	1
	Branches	5	.2	.447	0	1
	Multi-branches	5	0	0	0	0
	Sales and Services Revenues*	1	278.662	.	278.662	278.662
	Total Production*	3	245.105	66.867	206	322.314
	Net income*	1	21.16	.	21.16	21.16

Notes. *Average value computed between 2017 and 2020.
Source: Authors' elaboration on data from Orbis Bureau Van Dick database

Tab. 5: Characteristics of supply chains

Supply chain	Firm age			Firm size*			Multi-chain		With branches			Total
	0-5	6-24	25+	0-9	10-49	50+	No	Yes	No	Yes	Multi-branch	
Extra Virgin Olive oil supply chain	27	32	3	54	8	0	19	43	51	11	4	62
Wheat and derivates supply chain	14	33	8	49	6	0	25	30	49	6	2	55
Dried fruit and derivates products supply chain	15	13	0	24	4	0	8	20	25	3	1	28
Pulses, hemp, aromatic-officinal plants and their products and honey supply chain	5	14	4	19	4	0	2	21	18	5	1	23
Citrus fruit and citrus fruit products supply chain	4	12	3	18	1	0	5	14	15	4	1	19
Vegetables and their products supply chain	5	12	2	18	1	0	9	10	13	6	2	19
Livestock supply chain	3	5	4	11	1	0	9	3	10	2	1	12
Grape and grape products supply chain	3	6	1	9	1	0	2	8	7	3	0	10
Cheese supply chain	2	3	2	7	0	0	4	3	5	2	2	7
Prickly pear and prickly pear products supply chain	2	5	0	5	2	0	4	3	7	0	0	7
Exotic fruit and derivates products supply chain	1	3	1	5	0	0	2	3	4	1	0	5

Notes. *Average value computed between 2017 and 2020.
Only for those companies for which information could be found through Orbis.

Source: Authors' elaboration on data from Orbis Bureau Van Dick database

Tab. 6. Current management and control bodies

	Sex		Age			Total
	Women	Men	18-25	26-50	50+	
CEO	48	112	9	90	61	160
Board of Directors	14	47	5	32	24	61
Board of Auditors	4	9	0	6	7	13
Judicial Administrator	0	1	0	0	1	1
Partner	6	2	1	2	5	8
Other	0	3	0	0	3	3

Source: Authors' elaboration on data from Orbis Bureau Van Dick database

5. Findings

In this study, we describe the emergence of a digital platform ecosystem to enhance and integrate the distinctive features of rural areas. We structure our findings through the design and launch phases of the platform, highlighting the activities carried out at each stage to bring the ecosystem to life and populate it and the feelings of its actors. Specifically, we identify the role of the orchestrator as the project leader-designed as an external actor with no direct interest in supply chains-and its contribution to maximizing the ecosystem's value codiscovery potential.

5.1 Designing the digital platform ecosystem

The design phase describes the orchestrator's motivations for triggering the ecosystem creation process, followed by the design idea and the construction of the platform.

5.1.1 Development of a future vision for the rural arena

The project originated with an independent entity with a strong relational position in response to the need to enhance the rural areas of Sicily. In a context characterized by the poor capacity for aggregation on the part of the production system-due to the small size of enterprises and the low propensity for cooperation-the initiative was conceived as an opportunity to foster local collaboration aimed at enhancing the territory and its resources according to a participatory approach. In fact, KI-1 revealed, "[...] the project aims to network small businesses and foster a system approach between disadvantaged territories, from which to generate a common return. [...]. This is a very ambitious project aimed at making attractive inland areas dominated by feelings of distrust and abandonment".

Although embarking on a digital transformation journey was expected to be very difficult in such a change-hostile environment, the initiative was seen as an opportunity for a mindset change. KI-1 revealed, "Cultural resilience takes time, consistent messages, and the ability to convince businesses to change. Through the help of partners, we raise awareness of the digital transition among agricultural producers and provide them with all the assistance they need to persuade them to join a potentially revolutionary project for the area".

The complexity and ambition of the project justify its conception and management by an independent entity without economic interests, which takes on the role of orchestrator. KI-3 said, "You understand well that such a project would be neither thinkable nor feasible by individual companies".

5.1.2 Development of the project idea

The core of the project is the creation of a digital platform integrated with an international traceability standard to prove the Sicilian origin of agri-food products, to which targeted commercial interventions are added to promote an image of the products related to the specificities of the area. KI-2 explained, "[The project] intends to ferry rural communities into the world of digital technologies at the service of quality Sicilian food, certified according to the UNI EN ISO 22005 standard". To complement this, it envisages the creation of a direct sales circuit to market products and link the network of businesses with promotional and commercial initiatives carried out by regional, national, and international organizations and operators. KI-1 stated, "[Through these interventions] we would like to make very small local businesses visible in national and international markets [...] that alone could not make it". In addition, KI-3 stated, "The project provides an innovative solution that could in time also be integrated with other projects, such as food and wine tourism".

5.1.3 Designing the technological infrastructure

The project leader relied on an external agency to define the technical and organizational architecture of the digital platform, which was implemented

through public funds. Regarding its features, during the kick-off meeting, the certification agency stated, "We designed an Azure blockchain platform for digital traceability, in compliance with UNI EN ISO 22005, accessible to all companies that will join. It is a modular multichain architecture that allows each operator to record and share information about each agri-food product. Each adhering company will only have access to its own data, which will be immutable. In contrast, the project leader will have an overview and be able to access all the data". He added, "We defined smart contracts to regulate transactions within the platform and implemented a traceability system that may involve many digital technologies. In the future, it will be the basis for building innovative forms of communication, so-called smart labels, through which the end consumer, after framing a digital label on the foodstuff packaging with his smartphone, will be able to trace the product's origin".

As designed, the platform connects all participating companies, enabling them to create complementary offerings. Again, the certification agency said, "It [the platform] generates a complex network of linkages between multiproduct supply chains, which overcomes the traditional vertical view of each supply chain in favour of the rise of a cross-sector ecosystem, in which each actor will take on a defined role based on its position along the supply chain, i.e., farm and/or processor and packer".

5.2 Launching the digital platform ecosystem

The launch phase of the project required the orchestrator to find ways to "open" the platform to potential complements. Thus, the orchestrator shifted from an inwards focus in the conception phase to an outwards focus to attract users.

5.2.1 Development of consensus

The strategies implemented by the focal actor to develop consensus among potential complements focused on the promotion of the ecosystem as a certification system to enhance the economic and social potential of local products and the entire territory. Often, the project leader leveraged public and private partners with strong local roots to present the platform and its objectives to potential users. KI-10, KI-13, KI-14, KI-15, and KI-22 stated that they got to know about the project thanks to their trade associations during meetings where the focal actor was present. KI-10 explained, "[During one meeting] he described the project in broad outline, convincing me to look into it further in the following days". On the other hand, KI-20 stated, "I got to know [the initiative] thanks to a discussion with a project partner company that operates in the same supply chain as us".

In addition, the orchestrator organized informational meetings on the project and again used partners to encourage the participation of member companies. For example, the professional associations-partners in the initiative-entered into advantageous agreements with the orchestrator, awarding training credits to members.

However, a few companies that were interviewed judged the promotional efforts made by the orchestrator to attract more traditional companies to the platform as still too weak due to cultural resistance typical of the rural world. For this reason, KI-2 hoped for more publicity efforts. He stated, "The orchestrator must facilitate early participation, emphasizing the urgency of the ecosystem to overcome the digital divide that characterizes peripheral territories". According to KI-9, some companies may join the project in the future. He stated, "Currently, more traditional companies do not understand the advantage that digital traceability certification offers. Despite these promotional efforts, many local companies have chosen not to join the project. To convince reluctant companies, showing them a definite advantage, such as returns from the market, will probably be necessary".

5.2.2 Empowering ecosystem actors

The orchestrator promotes free training courses on the use of digital technologies and leverages partners to incentivize the participation of their member companies. Once again, the professional associations-partners in the initiative-enter into advantageous agreements with the orchestrator, awarding training credits to members. In this regard, KI-1, KI-2, KI-3, KI-10, KI-12, and KI-19 agreed on the usefulness of training activities to assist companies in introducing and maintaining digital innovation. Specifically, KI-7 recognized the value of training courses in less structured, family-run businesses where "often the owner is elderly and not very familiar with technology". In particular, KI-3 stated that, given the complexity of the project and the number of technologies involved, training activities are essential to moving companies towards cultural change and making them autonomous in the management of digital tools. In fact, without such actions, digital tools risk becoming just an expensive frill for the participating companies. According to KI-7, "those who do not have these skills will slow down all the others. Ad hoc training courses allow us all to start from the same level".

However, some companies' representatives negatively evaluate the communication strategy implemented by the orchestrator and call for its improvement. For example, KI-8 said, "There is a need for better communication of what the project envisages in practice. Some of our suppliers do not want to participate because they do not understand what they have to do (i.e., keeping formal records). Not being able to include them in the traceability system will be detrimental to us". Similarly, KI-6, KI-10 and KI-11 recognized the value of effective communication, through which a growing number of companies will be able to understand the project and its potential benefits. As a result, companies will be able to organize themselves to welcome change.

5.2.3 Governing the ecosystem

The orchestrator is responsible for defining the game's rules, codified within a regulatory framework and providing confidentiality agreements

for sensitive data. Additionally, the project leader will monitor the correct application of the established procedures through periodic checks and appropriate tools, such as traceability tests and mass balances. On this matter, KI-3 stated, "The orchestrator is the data owner. He keeps an eye on all the information at the dashboard level, which individual companies are not able to access for privacy reasons". Furthermore, KI-8 recognized the orchestrator as "the entity that dictates the guidelines and periodically checks that all the companies-and there are many of them-are doing things correctly". Many interviewees evaluated the role of the orchestrator positively. In this vein, KI-4 and KI-6 agreed to define the orchestrator as "a point of reference" to whom they can discuss internal rules. Instead, KI-3, KI-10 and KI-17 defined the orchestrator as key intermediary entity that coordinates all project-related activities in a constant, structured, and precise way. Specifically, KI-3 stated, "It would be impossible to imagine a project of this tenor, of this innovative scope, without the presence of the orchestrator, without his coordination and, above all, without his intermediary activity".

However, some interviewees complained about the absence of an adequate number of consultants to support the orchestrator, on the one hand, in control activities and, on the other hand, in handling requests for clarifications from companies. Once participation in the platform grows and extends to smaller and less structured companies, it will become almost impossible to meet everyone's needs. For this reason, KI-7 said, "There needs to be more consultants placed alongside the orchestrator so that they can talk to the individual companies in depth and accompany them step by step through the digital transformation process".

6. Discussion

In an innovation-hostile environment, digital platform ecosystem emergence may occur when an independent entity with a strong relational position, assisted by public and private partners rooted in the territory, engages in a range of activities tailored to rural communities framed in the ecosystem design and launch phases. In the first stage, the orchestrator conceives of the ecosystem; in the second stage, he brings together and leverages the resources and capabilities of third parties to attract potential users, initiate the ecosystem and manage the digital transformation process.

6.1 Theoretical implications

Responding to the call for more contextualized studies (Gulati, Puranam, and Thusman, 2012; Jacobides, Cennamo, and Gawer, 2018), this paper contributes to the recent literature on ecosystems through an in-depth longitudinal study on the emergence of a digital platform ecosystem in rural areas as a tool for local development. The empirical context of our case study complements the predominant focus of previous literature; we analyse ecosystem emergence in a low-tech rather than a high-tech sector (Gawer & Phillips, 2013), driven by an independent actor rather

than an established enterprise (Stonig, Schmid and Müller-Stewens, 2022), operating for collective interests rather than personal ends (Shih, Pisano, and King, 2008), and in peripheral areas hostile to innovations rather than lively (Dittrich, Duysters, de Man, 2007). Moreover, our study extends the research on ecosystem emergence stages (e.g., Jha *et al.*, 2016; Cinici, 2018), focusing on the ignition phase. Specifically, we identify two key moments, namely, ecosystem design and launch, i.e., when the focal actor plans the ecosystem and develops a set of strategies to initiate it. While the prevalent perspective (e.g., Addo, 2022; Hammer and Frimanslund, 2022; Cinici *et al.*, 2019) describes ecosystem emergence as a bottom-up process of collective discovery and negotiation, our results reveal a top-down, imposed value blueprint (Adner, 2017). We show that, in a rural environment, the ecosystem is successfully initiated when a focal actor, after assessing systemic and contextual conditions, develops a value proposition related to the actual development needs of potential users and when he or she implements a set of activities necessary for its realization (Ansari, Garud and Kumaraswamy, 2016; Batterink, Wubben, Klerkx and Omta, 2010; Boon, Moors, Kuhlmann, Smits, 2008). First, he or she designs a multiactor, modular and scalable platform that enables the coordination of users and their resources and the cocreation of value within the ecosystem. Second, a set of strategies is developed to stimulate membership and foster innovation in dispersed areas. By leveraging public and private partners, the focal actor publicizes digital platforms and promotes training activities (Rogers, 1961; Pan Fang *et al.*, 2021). To attract participation in events, an incentive-based persuasion strategy is implemented. The focal actor reduces the risk of nonmembership in the ecosystem or later defection, facilitating its ignition and allowing it to overcome the chicken-and-egg-type problems that are typical of multisided platforms (Addo, 2022; Evans, 2009; Evans and Schmalensee, 2016). Third, the focal actor takes the lead in the ecosystem and manages the innovation process, setting the rules of the game and performing periodic checks (Autio, 2021).

6.2 Practical implications

The empirical findings of this study underscore the pervasive influence of marginality in rural contexts on local communities' economic conditions and quality of life, consequently impeding the developmental potential of micro- and small enterprises. Conventional, centralized policies that focus solely on funding and promoting digital infrastructure often prove inadequate at addressing the nuanced challenges faced by these communities (Salemink *et al.*, 2017).

A novel approach emerges from the examination of successful interventions, namely, targeted local digitalization projects that address both connectivity and inclusion issues. In contrast to the prevailing discourse that tends to overlook the role of local governance, our study accentuates the pivotal position of local government. Often the unrecognized orchestrator in managing rural development, local government stands as the level of governance closest to everyday life. Acting in collaboration with civil society organizations and the private sector (Douglas, 2005)

catalyses change. Our research posits that the ignition of rural territories and community development should emanate from strategic local and regional policies. When championed by stakeholders intimately acquainted with the terrain, these policies can give rise to projects that amplify the unique strengths of these peripheral areas. As a result, our paper offers valuable insights to policy-makers, guiding them in formulating policies that empower regional administrations to nurture similar projects in marginalized territories.

Simultaneously, this study serves as a handbook for local administrators, imparting crucial lessons on how to champion the cause of marginal territories. It emphasizes the imperative of recognizing rural areas' specificities and needs, advocating for collaborative partnerships between public and private entities. Through joint efforts, these partnerships can spearhead development by implementing shared digitization projects and fostering a range of actions that actively engage and support local businesses.

Moreover, our research illuminates the journey of rural micro- and small enterprises towards technology adoption. Despite initial resistance to change, these enterprises exhibit a remarkable willingness to embrace technology when provided with guidance and support in the digital transformation process. In this context, technology is a pivotal driver of the emergence of these ecosystems, acting as a catalyst for innovation and collaboration. The integration of digital tools and platforms not only facilitates streamlined communication and knowledge sharing but also accelerates the coevolution of interconnected entities towards common territorial development goals. Embracing technology, as a core element of ecosystem development, ensures that these initiatives are sustainable and capable of adapting to the dynamic landscape of the digital era. Top-down digitalization projects emerge as facilitators, enabling access to specialized skills and knowledge, expediting the learning curve, and mitigating perceived risks through shared experiences. Central to this process is the ecosystem created by collaboration with other organizations. This ecosystem acts as a platform for interaction and cooperation, fostering a coevolving vision aligned with common territorial development goals. Strategic decisions to reengineer intra- and intercompany processes become more informed and adaptive, reflecting broader technological adoption. However, organizations aiming to cultivate such ecosystems must embody traits of receptivity, flexibility and take a proactive stance towards organizational and operational changes. This adaptability is vital for facilitating the development and evolution of ecosystems, creating an environment where innovation thrives and permeates the entire community.

Our study advocates for a paradigm shift towards localized, inclusive digital initiatives guided by responsive policies. By recognizing the potential of local actors and fostering collaborative ecosystems, these initiatives can usher in a transformative era for rural development, unlocking the latent capabilities of marginalized territories and empowering local businesses to thrive in the digital age.

7. Conclusion

As part of a broader research project, the present study explores the mechanisms underlying the innovative efforts of traditional sectors operating in rural areas. In particular, we explore the opportunities and threats specific to rural contexts, focusing on how complex interrelated organizations can thrive and develop rather than fail to scale up. Despite being in an exploratory stage, the project will allow us to observe and closely monitor the evolution of such a digital ecosystem, shedding light on the role of external orchestrators and the relationships among the other actors. Although digital platform ecosystems have been the subject of several studies in the agri-food sector, there is no comprehensive and exhaustive exploration of the phenomenon within a rural area where ecosystem participants join efforts to create value in an innovation-hostile environment.

This study is limited to companies operating against the backdrop of a shared project to create a digital platform ecosystem. The youthfulness of the project forced us to limit our study to only the initiation stage of the digital platform ecosystem for value codiscovery. In the future, the study could be extended to the momentum stage of the ecosystem to provide additional consistency with our results. Finally, for the time being, the project's uniqueness makes it impossible to compare it with other similar cases in the national context.

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sinergie
italian journal of management
Vol. 42, Issue 1, 2024

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sinergie
italian journal of management

ISSN 0393-5108
ISSN 2785-549X
DOI 10.7433/s123.2024.07
pp. 165-188

FONDAZIONE CUEIM

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Reaching the SDGs by 2030: At what point is Italy? Evidence from firms at the regional clusters' level

Received
28th March 2023
Revised
22nd May 2023
Accepted
4th March 2024

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Abstract

Framing of the research. *The implementation of the SDGs, one of the most urgent and current challenges, requires adaptation to sub-national contexts and the involvement of many actors, including firms.*

Purpose of the paper. *The paper examines the Italian situation regarding the achievement of the SDGs through the lens of the adoption of the 2030 Agenda by firms from different Italian regions.*

Methodology*. The research involved 30 Italian listed companies from Northern and Central-Southern Italy, selected from the CONSOB's list of firms providing a non-financial declaration. An integral reading of the documents with subsequent interpretation was performed.*

Results*. Regional localization does not affect the overall contribution to the SDGs, which is limited for all firms. Instead, the geographic localization of firms at the regional scale differentiates the prioritized SDGs: Northern firms are more oriented towards social and economic SDGs, while Central-Southern firms focus more on environmental ones.*

Research limitations*. The paper represents a preliminary exploration of Italian firms' advancements towards the SDGs over a regional space. Future research developments could focus on sample enlargement and the exploration of sub-national specificities in other countries around the world.*

Managerial implications. *Italian firms should enhance their commitment to the 2030 Agenda in all its ambitions by incorporating the sustainable goals within their corporate culture and strategic posture.*

Originality of the paper. *The study responds to the need to consider sub-national specificities in the literature on sustainable development by capturing the connections between firms, their territory of operation, and the SDGs.*

Key words: *2030 Agenda for sustainable development; sustainable development goals; SDG contribution; geographical localization; regional clusters; Italy*

1. Introduction

Biodiversity loss, climate change, and widening inequalities are considered 'wicked problems' (Waddock and McIntosh, 2011) that urgently need to be addressed to shift the world onto a sustainable and resilient path. In 2015, the United Nations (UN) issued a global call for protecting the planetary and human future by publishing the 17 Sustainable Development Goals (SDGs) to be achieved by 2030. In 2019, the UN Secretary-General called for a "Decade for Action" to fully operationalize the 2030 Agenda for

Sustainable Development. Its accomplishment has become a global priority because more than one-third of the 2015-2030 period has passed, and the already slow advancements towards the goals have been further hindered by the Covid-19 outbreak (UN, 2021). The latter has compromised the capacity to overcome the unsustainability of modern production and consumption patterns, making the call to "leave no one behind" even more urgent (Biggeri *et al.*, 2021). As a result, the need to accelerate progress towards goal achievement is evident in civil society, among policymakers, and scholars (Pastore and Ugolini, 2020).

In this context, the emphasis on the implementation of the SDGs varies by geographic area, necessitating further analysis of local contexts to develop a comparative analysis that delineates progress towards sustainable development over space (Salvia *et al.*, 2019; Liu, 2021). The goals of the 2030 Agenda recognize the importance of action across all scales - global, national, and sub-national - to achieve a sustainable future (Szetey *et al.*, 2021). The SDGs must take into account regional and country-level starting points: goals and targets conceived for all nations must be adapted to sub-national realities because there is significant variation between and within countries (Nicolai *et al.*, 2015), and diversities among different sub-national areas are a prerequisite for sustainability at the national level (Clarke and Lawn, 2008; Pulselli *et al.*, 2012). Local communities, in fact, have heterogeneous sustainability needs, requiring global goals and targets to be tailored to align with local priorities (Moallemi *et al.*, 2020). In this sense, SDG localization is a flexible process that encompasses the downscaling of goals to the local level by identifying a subset of SDGs or a group of SDG targets relevant to the local scale (Szetey *et al.*, 2021).

The adoption and diffusion of SDGs have been investigated at national and supranational levels (Suriyankietkaew and Nimsai, 2021), and comparative studies looking at differences among countries in SDGs achievement start to appear in academia (e.g., Garcia *et al.*, 2017; Reverte, 2022; Kuc-Czarnecka *et al.*, 2023). Conversely, studies at regional and local levels are scarce, which can determine strong structural disparities, and comparisons at the regional level are still limited (D'Adamo *et al.*, 2021), despite increasing awareness of the importance of SDG localization (Jones and Comfort, 2020). According to Yin *et al.* (2023), research on the SDGs still requires further investigation, moving away from a macro-level-centered approach to a micro-level focus.

The paucity of studies based on a regional perspective represents an important gap because regions, intended as the spatial scale below a state, are the most appropriate scale for studying sustainability. Environmental functioning and human activities interact most intensely at this scale, and their balance is crucial for studying and addressing sustainability issues (Salimzadeh *et al.*, 2013). Moreover, the acceleration of sustainable solutions addressing the world's biggest challenges (e.g., public health, poverty, gender, climate change, etc.) involves especially the local level (Biggeri *et al.*, 2021). There, inequalities, exclusions, and vulnerabilities are most immediately experienced because the interactions between authorities, institutions, and citizens are strongest and most immediate. Thus, regional and local contexts represent the most proximate socio-institutional settings

that directly affect individual and collective capabilities, as distinctive ecosystems in which history, culture, geography, resources, knowledge, and institutions converge (Biggeri *et al.*, 2018). Recognizing and nurturing these local endeavors becomes essential to ensure their effectiveness and integration into the broader global mission of achieving the SDGs. In this direction, the UN itself gives visibility to SDG practices at the local level through the Local 2030 initiative (Local 2030, 2023), highlighting the crucial role of local efforts. The centrality of SDG territorialization is also expressed by the promotion of Voluntary Local Reviews, documents in which local governments share their experience of territorialization of the 2030 Agenda's targets, related to the responsibilities and abilities of local governments to provide basic services to citizens (Richiedei and Pezzagno, 2022).

Overall, further research in various regions is encouraged to enrich the limited body of knowledge in this field and enhance SDG adoption (Miocevic and Srhoj, 2023; Montera *et al.*, 2023). Furthermore, the necessity of considering sub-national specificities, giving attention to the territory, is even more important for Italy, a country historically characterized by strong regional specificities and differences, which find their radicalization in the so-called North-South gap (Alaimo and Maggino, 2020).

On these bases, this paper aims to examine the Italian situation regarding the achievement of the SDGs to highlight potential territorial differences or homogeneity through the lens of the adoption of the 2030 Agenda by firms from different Italian regions. This firms' perspective is chosen due to the acknowledgment that the sustainable development agenda cannot be achieved without business (UN, 2015). Thus, all firms - regardless of their country, size, and industry - are called to make an important contribution in the SDGs era. Palau-Pinyana *et al.* (2023) conducted a systematic literature review on SDG implementation in the private sector, and a research question on the local roles played by organizations emerges as still open. Moreover, the same authors state that empirical studies should analyze the situation in certain regions, allowing the comparison of results among companies. Thus, the following research question (RQ) arises: *Does geographic localization of firms at the regional scale differentiate the contribution of Italian firms to the SDGs?*

With this in mind, we conducted empirical research based on secondary data, answering the call of some scholars (van der Waal *et al.*, 2021; Mio *et al.*, 2020) who have invited academia to empirically study firms' contributions to the SDGs. Most studies are conceptual and interpretative; thus, they underline fundamental aspects of the topic but without delineating the trends at scale (Calabrese *et al.*, 2022). The research involved 30 Italian listed companies from different regions, selected by the Italian National Commission for Stock-Exchange Market (CONSOB)'s list of firms providing a non-financial declaration (NFD).

The findings reveal that geographic localization does not differentiate the overall SDGs contribution of Italian firms, which show a low effort regardless of the regional macro-area of belonging. Conversely, geographic localization affects which SDGs are prioritized by sample firms.

This paper provides some theoretical and practical contributions. First, we attempt to fill the need for considering sub-national specificities in the literature on sustainable development (Salvia *et al.*, 2019; Liu, 2021) by capturing the connections between firms, belonging territory, and SDGs. To maintain the comparability of the results, the analysis is based on global data available in the public domain. Second, the multiple dimensionalities of the SDGs are considered without computing indices or averages that impose autonomous weights. Third, the results of the analysis are interesting for policymakers and government authorities to regulate the pursuit of sustainability goals and should put in place appropriate regional-level targets, along with flexible implementation plans.

The remainder of this study is organized as follows. After a literature review on the 2030 Agenda and factors influencing firms' contributions to SDGs (Section 2), the method is explained (Section 3), followed by the description and discussion of the findings (Sections 4 and 5). Finally, this study proposes theoretical and managerial implications and concludes with limitations and possible directions for future research (Section 6).

2. Theoretical background

2.1 2030 Agenda for sustainable development and firms' contributions

In the UN resolution "Transforming our world: the 2030 Agenda for Sustainable Development" (UN, 2015), the adherent states established 17 goals, 169 related targets, and more than 230 indicators as guidelines, covering nearly all fields of life, to globally undertake a balance between economic progress, environmental protection, and the safeguarding of social interests, with consideration for future generations (Mio *et al.*, 2020; Martinoli, 2021). Since then, contemporary sustainability literature has focused on the various SDGs outlined by the UN, embedding the three pillars of sustainability: economic, social, and environmental (Capobianco *et al.*, 2022).

In light of a more ambitious vision of transformative change towards achieving a more sustainable future by 2030, the SDGs represent an evolution of their predecessors such as the Millennium Development Goals (MDGs), whose deadline was reached in 2015. The MDGs aimed at eradicating poverty and improving health conditions within developing countries heavily reliant on funding from wealthier nations (Van Zanten and Van Tulder, 2018). Conversely, the SDGs guide economic growth, social development, and environmental sustainability globally, within both developed and developing countries (Pizzi *et al.*, 2021). Moreover, the SDGs focus not only on international cooperation but also on sustainable development within countries through a collective effort by governments, civil society, and public and private organizations (Kumar *et al.*, 2016). Finally, the SDGs place greater emphasis on environmental sustainability than was expressed by the MDGs (Griggs *et al.*, 2013). The SDGs remain an agenda adopted by 178 countries and territories (Afandi *et al.*, 2021).

In summary, the distinguishing features of the 2030 Agenda are the principles of universality and indivisibility: universality implies that the SDGs apply to all nations and actors globally, regardless of their current level of income or sustainability challenges; whereas, indivisibility means that the implementation of the SDGs should be based on integrated approaches rather than on siloed knowledge and policymaking (Bennich *et al.*, 2020).

In terms of SDGs formulation, the goals are briefly described herein (UN, 2016), highlighting the multidimensionality of sustainability challenges (Table 1).

Tab. 1: Overview of SDGs

SDGs	Description
SDG 1 *No poverty*	Reduction of poverty by half the world people through nationally appropriate social protection systems to create the basis for an integrated and inclusive economic development
SDG 2 *Zero hunger*	Provision of safe, nutritious, and abundant food to people, also promoting a sustainable agriculture
SDG 3 *Good health and wellbeing*	Reduction of the global maternal and children mortality caused by infectious and chronic diseases
SDG 4 *Quality education*	Filling the education gap between males and females by providing them with completely free, equitable and quality opportunities to gain pre-school, primary and secondary education
SDG 5 *Gender Equality*	Elimination of all forms of violence against women and girls in the public and private spheres, and pink endorsement in decision-making and leadership roles
SDG 6 *Clean water and sanitation*	Access to clean drinking water and hygiene facilities
SDG 7 *Affordable and clean energy*	Access to affordable, reliable, sustainable energy for all by implicating an energy infrastructure expansion which leads to an increased economic activities and employment opportunities
SDG 8 *Decent work and economic growth*	Provision of labor standards in line with human dignity, equal employment opportunities for all, also eradicating unemployment and child labor
SGD 9 *Industry, Innovation, and infrastructure*	Inclusive and sustainable industrialization by leveraging on technology, innovation and sustainable infrastructure,
SGD 10 *Reduced inequalities*	Development of the conditions of countries being at the bottom of the pyramid, also helping them to fight the internal economic, social and political challenges.
SGD 11 *Sustainable cities and communities*	Improvement of living standard of the general population by ensuring good quality and safe housing access, sustainable transportation, and availability of support services
SDG 12 *Responsible consumption and production*	Encouragement of both manufacturers and consumers to show responsibility towards the consumption of resources
SDG 13 *Climate action*	Fight against climate change and its impact
SDG 14 *Life under water*	Promotion of the sustainable use of the ocean, seas, and marine resources
SDG 15 *Life on land*	Preservation of biodiversity along with ecosystems
SDG 16 *Peace, justice, and strong institutions*	Promotion of peaceful and inclusive societies with equal access to knowledge and justice services
SDG 17 *Partnership for goals*	More collective efforts towards the adoption of all the other SDGs

Source: our elaboration

In realizing the SDGs, the governments of the UN member states are not the only actors involved: in fact, the sustainable development agenda cannot be achieved without businesses that are considered as sustainable development agents (Mio *et al.*, 2020). Thus, all firms of any country, size, and industry are called to give an important contribution in the SDGs era by appealing to their creativity and innovation to generate value for the common good (UN, 2015). Previous literature has already recognized the key role of businesses in achieving sustainable development (Wicki and Hansen, 2019; Garcia-Sanchez *et al.*, 2020; Cerquetti and Montella, 2021).

SDGs' implementation by firms implies the adoption of strategies and practices supporting the SDGs (Grainger-Brown and Malekpour 2019), integration of these goals into business activities (Biggeri *et al.*, 2019), and reporting activities on them (Zemanová and Druláková, 2020). In doing so, several advantages can be obtained in terms of overall sustainable development but also at the company level.

In terms of overall sustainable development, the private sector engaging in SDGs can provide opportunities for entire economies of countries, not only contributing to the creation of societal value (Buhmann *et al.*, 2019) but also reducing the scale of money laundering activities, which weaken domestic economies (Dobrowolski and Sułkowski 2020). In this vein, multinational enterprises (MNEs) play a crucial role in adopting SDGs as part of their ordinary investments. In this way, MNEs can increase knowledge, wealth, and health, and reduce negative externalities consisting of the overuse of natural resources, harm to social cohesion, and overconsumption (Kolk *et al.*, 2017; Montiel *et al.*, 2021). Thus, foreign subsidiaries are also called to implement SDGs (Liou and Rao-Nicholson, 2021; van Tulder *et al.*, 2021). In addition, small and medium enterprises and other for-profit firms can contribute to environmental preservation and economic development (Palau-Pinyana *et al.*, 2023).

At the company level, SDGs' implementation acts as a lever for improving sustainability performance (Caldera *et al.*, 2018), for achieving a competitive edge in the industry (Jayaprakash and Radhakrishna Pillai, 2018), as well as for increasing stakeholders' preferences for companies (Yamane and Kaneko, 2022), and even for better facing global crises such as the COVID-19 outbreak (Mattera *et al.*, 2021).

2.2 Factors influencing the firms' contributions to SDGs: The geographic area

There is still scant evidence on the factors influencing firms' contributions to SDGs since corporate engagement in the 2030 Agenda is a novel phenomenon (Van der Waal and Thijssens, 2020; Calabrese *et al.*, 2022). An important knowledge advancement is provided by a recent systematic literature review that maps specific enablers and their combination for SDG implementation in the private sector (Palau *et al.*, 2023). Some enablers are classified as endogenous to the firm's environment, which include the company's characteristics, its governance, and the solutions related to innovation and technology that each company can adopt. Among endogenous enablers, pioneering studies have identified firm size as a key antecedent of corporate contribution to sustainable goals.

In this regard, companies of greater size are characterized by a higher likelihood of SDG involvement because they are more visible and subject to greater stakeholder attention than smaller companies (Khaled *et al.*, 2021). Moreover, Mattera and Ruiz-Morales (2021) state that small-medium enterprises contribute to the SDGs less than multinationals that have a higher global presence, also in developing countries where the SDGs are particularly relevant (Van der Waal and Thijssens, 2020).

Another typology of enablers is labeled by Palau *et al.* (2023) as external to the environment of the company and comprises a set of exogenous forces that could affect the organization. These enablers include the industry, the available tools needed to thoroughly put SDGs into practice, and education. Focusing on the firm industry, scholars demonstrate that the firms belonging to industrial sectors more likely to cause social and/or environmental damage (i.e., so-called sensitive sectors) significantly contribute to the SDGs (Cosma *et al.*, 2020; Emma and Jennifer, 2021). In addition, Tsalis *et al.* (2020) suggest that firms in the metal product, energy, and telecommunication sectors perform better in terms of the SDGs' adoption, while firms in the real estate industry show a low level of commitment toward the 2030 Agenda (Ionaşcu *et al.*, 2020).

Among external enablers, the geographic area in which businesses are located also affects the SDG involvement. The firms in developed countries contribute to the SDGs more than those in developing and underdeveloped countries due not only to the different availability of resources for devoting to such goals (Rosati and Faria, 2019; Biglari *et al.*, 2022) but also the disparities in the countries' institutional settings (van der Waal and Thijssens, 2020). These institutional differences are related to country-specific legal origin (civil vs. common law), investors protection rights (strong vs. weak), national culture (ESG-averse vs. ESG-seeking), and corruption level (low vs. high) characterizing the institutional surroundings under which firms are embedded (DasGupta and Roy, 2023). Thus, political instability, corruption, and labor conditions lead the emerging market firms to face greater risks in pursuing sustainable goals than developed market firms (Clark *et al.*, 2015).

The heterogeneous contribution to the SDGs by firms from different countries of origin is recently under investigation (i.e., Garcia *et al.*, 2017; Reverte, 2022; Kuc-Czarnecka *et al.*, 2023), while there is paucity of research on the potential differences in the ESGs adoption by firms across regions of the same country. Prior studies examine regional performance in terms of progress towards the SDGs - some of them are referred to Italian regions (Alaimo and Maggino, 2020; D'Adamo *et al.*, 2021; Cavalli *et al.*, 2021). The premise is that the process of defining policies and actions aimed at achieving the 2030 Agenda requires considering the territory. It is the result of the interaction of the same subsystems (environmental, economic and social) of sustainable development: the territory is a geophysical space, corresponding to a specific socio-cultural identity, in which certain economic and social relations occur and develop (Alaimo and Maggino, 2020). Place-specific conditions - related to political, cultural, educational, and economic institutional framework surrounding firms - provide barriers or incentives for SDGs implementation and compliance, affect

firms' sustainability performance by defining the "rules of the game" that grant them legitimacy, and can influence the adoption, scope, and quality of sustainability reporting. Nilsson *et al.* (2016) highlight the importance of key contextual determinants, such as geographical conditions, when it comes to working with the SDGs. Especially, the regional resource base makes a big difference. According to Ansell *et al.* (2022), the resources owned by local firms and aimed to promote the achievement of SDGs are named NATO resources standing for: a) Nodality: actor's connections to other actors' resources; b) Authority: actor's position and legitimacy; c) Treasure: financial and organizational resources of an actor; and, d) Organizational capacity in terms of problem-solving or organizing fruitful interactions with other actors. In addition, Medeiros (2021) evidences a "territorial dimension" to the sustainable development understanding because the SDGs incorporate a myriad of territorial scales for policy intervention: urban, peri-urban, rural, local and subregional, regional, national, and international.

Anyway, to the best of our knowledge, regional comparisons based on local firms' contribution to the SDGs are lacking. On the contrary, the key roles of firms should not be neglected in the transformation toward sustainability at the regional scale: in fact, the firms are local actors having first-hand knowledge about both context-specific problems and challenges and thereby are able to easily adapt the SDG goals and targets to local conditions (Ansell *et al.*, 2022). Thus, scholars have recently called for further regional comparisons in this research area (D'Adamo *et al.*, 2021), and the present study moves in this direction.

3. Method

3.1 Research setting

This study considered Italy as an appropriate research setting because the need to consider sub-national specificities, focusing on the territory, is highly important for such a country. Since the beginning of the 20th century, Italy has been characterized by marked regional specificities and differences, upon which the so-called North-South gap is built (Alaimo and Maggino, 2020). The strong differences in the territorial development of Italy (i.e., in terms of lower per capita GDP, unemployment rate, child mortality rate, rate of waste recycling, etc.) represent a "prototypical case of seemingly intractable within-country disparities" (Bigoni *et al.*, 2019, p. 1).

To identify the firms to be included in this study, we focused on the Consob's list, which contains Italian companies with ordinary shares listed on the Italian Stock Exchange and which issued a NFD in 2022. According to Directive 2014/95/EU, NFD discloses to firm stakeholders the main corporate non-financial information to communicate the development, performance, position, and impact of firm activity, in terms of environmental, social, and employee matters, respect for human rights, anti-corruption, and bribery matters (Mazzotta *et al.*, 2020). The choice to look at the NFDs is due to the following two reasons: firstly, the

consideration that the above-mentioned EU Directive has given impetus to the reporting of not only non-financial information but also, presumably, issues related to the SDGs; secondly, the availability of public data since the NFDs are published on corporate websites.

Given the centrality of the regional perspective herein adopted, firms of the Consob's list are grouped into regional macro-areas according to where their headquarters are established, such as North of Italy (Piedmont, Valle D'Aosta, Lombardy, Liguria, Trentino Alto Adige, Veneto, Friuli Venezia Giulia, Emilia Romagna), and Central-South of Italy (Tuscany, Umbria, Marche, Lazio, Campania, Abruzzo, Molise, Puglia, Basilicata, Calabria, Sicily, Sardinia) (Gazzola *et al.*, 2020).

At this point, being a preliminary investigation to be extended in the future, we have deliberately restricted the study to the first 30 companies of the Consob's list by following this approach: 5 firms in Lombardy, 5 in Veneto, and 5 in Emilia Romagna that represent the new industrial triangle of Northern Italy (Fortis, 2023); 5 firms in Lazio, 5 in Tuscany, and 5 in Campania, Sicily, and Puglia, where there is the highest number of active businesses in the Central-South area (www.infocamere.it) (Tab. 2).

Tab. 2: The first 30 companies of the Consob's list and their geographical localization

North of Italy	Lombardy	A2A Spa
		Amplifon Spa
		WeBuild Spa
		Brembo Spa
		Recordati Industria Chimica e Farmaceutica Spa
	Veneto	Safilo Group Spa
		De' Longhi Spa
		AcqueVenete Spa
		Zignano Vetro Spa
		Dovalue Spa
	Emilia Romagna	Aeroporto Bologna Spa
		Hera Spa
		Interpump Group Spa
		Aimag Spa
		Bper Banca Spa
Central-South of Italy	Lazio	Leonardo Spa
		Terna Spa
		Enel Spa
		Eni Spa
		Atlantia Spa
	Tuscany	Piaggio & C. Spa
		Salvatore Ferragamo Spa
		Kedrion Spa
		Eukedos Spa
		Estra Spa
	Campania, Sicily, and Puglia	La Doria Spa
		Seri Industrial Spa
		Mediocredito Centrale- Banca del Mezzogiorno Spa
		Banca di Credito Popolare Scpa
		Banca Agricola Popolare di Ragusa Scpa

Source: our elaboration

The cut-off of 5 firms is due to the limited number of companies from the Consob's list located in Southern regions, which are generally less industrialized than those in the North. This cut-off has been applied uniformly across all macro-areas to ensure the sample's uniformity, thereby reducing potential biases associated with the underrepresentation of Southern firms and the overrepresentation of those located in Northern Italy.

3.2 Data collection

In December 2022, data were collected from secondary sources, such as non-financial information provided in individual NFDs (or consolidated NFDs in the case of groups), available on the corporate websites of the firms listed in Table 2. The primary advantages of gathering secondary data include time-saving and the ability to access a large amount of data that would otherwise be difficult to collect independently (Johnston, 2017). Reports were selected based on three inclusion criteria: public accessibility, publication in 2021, and verification by a third-party organization to ensure the disclosure of more reliable information (Diaz-Sarachaga, 2021). By adhering to these criteria, high-quality input data, characterized by relevance and homogeneity, were obtained. The application of these criteria to the entire dataset yielded 30 usable NFDs.

Information from the NFDs was integrated and cross-referenced with other reliable sources, including annual reports (specifically management reports), social, sustainability, and integrated reports. Additionally, abstracts of strategic plans presented to investors during roadshows and available in the Investor Relations section of corporate websites were reviewed. Furthermore, specialized press, including the prominent Italian economic newspaper Il Sole 24 Ore, and top management magazines, served as additional data sources. Triangulation was employed to examine the phenomenon from various perspectives, enrich our understanding of the issue under investigation, and assess the convergence of evidence (Jick, 1979).

3.3 Data analysis

A content analysis was conducted to elicit SDG-related information from various sources, critically evaluate them, and understand the firms' impact on the 2030 Agenda (Calabrese *et al.*, 2021; Silva, 2021; Gunawan *et al.*, 2020). The content analysis was performed manually in line with existing literature (Cosma *et al.*, 2020; Silva *et al.*, 2021) for two main reasons: firstly, much of the SDGs information was associated with the use of icons for the 17 goals, which cannot always be processed by content analysis software (e.g., Wordstat 7, Nvivo, TLab); secondly, the qualitative information to be interpreted was highly heterogeneous and not always present in the standard sections of the analyzed reports. Instead, a thorough reading of the documents followed by the interpretation of the contents was carried out.

All 30 reports were read in full, and the firms' contributions to the SDGs were assessed on a 0-4 scale, providing a more detailed picture than a Boolean scale. According to Calabrese *et al.* (2022), the five different levels of contributions are as follows: i) 0 if there is no contribution to any SDGs; ii) 1 if SDGs are mentioned as broad statements but without a plan to take action; iii) 2 if SDGs are mentioned and there is a narrative wording about plans to address them; iv) 3 if SDGs are mentioned but firms do not provide progress towards the stated SDGs; v) 4 if SDGs are mentioned with quantitative achievements. Any discrepancies in the assigned scores were discussed and resolved by the authors.

To facilitate data analysis, the 17 SDGs were clustered into three groups based on existing literature (Kumar *et al.*, 2018; Szennay *et al.*, 2019), resembling the three pillars of sustainability. Thus, the economic group comprised SDGs 8, 9, 11, 12, and 17; the social group included SDGs 1-5, 10, and 16; and the environmental group consisted of SDGs 6, 7, and 13-15. Subsequently, the overall score for the 17 SDGs and the scores for economic, social, and environmental SDGs were converted to an ordinal scale measuring low, medium, and high impact (Calabrese *et al.*, 2022). The ordinal scale was developed as follows: the scores of each group of SDGs were summed up to produce one score for each report. These scores were then divided into three intervals: low (the interval with the lowest scores), high (the interval with the highest scores), and medium (the other interval). The aggregated scores for each group of SDGs in each report were categorized into the corresponding interval.

After these steps, the data were analyzed through two contingency tables - one for Northern firms and the other for Central-South firms of Italy - where cells contained the number of reports with a specific score (high, medium, low) for each SDG group (economic, social, environmental, and overall SDGs). The two crosstabs were analyzed separately to determine if the variables (i.e., impacts and SDG groups) in each were independent, meaning that no relationship existed between them, and vice versa (Montera, 2018).

4. Results

A descriptive analysis of the sample reveals that many Northern firms operate in manufacturing industries (53.3%), providing industrial products (such as cables, pumps, brakes, etc.) mainly to business-to-business markets. In contrast, more than half of the Central-Southern firms operate in service industries (67%), particularly related to energy and financials, serving both business-to-business and business-to-client markets. In terms of firm size, the sample includes large firms whose workforce exceeds 250 units (European Commission, 2003).

Table 3 displays the total number of Northern firms for each SDG group along with the corresponding percentage in parentheses. For instance, the cells on the left indicate that Northern firms disclose a low contribution (46.6%) to overall SDGs; however, there is a focus on social (60%) and economic (53.3%) SDGs. The Pearson's Chi-square statistic has a value

of 23.258 (df = 4), indicating significance (p-value <0.01). Thus, the distribution in Table 3 is not random.

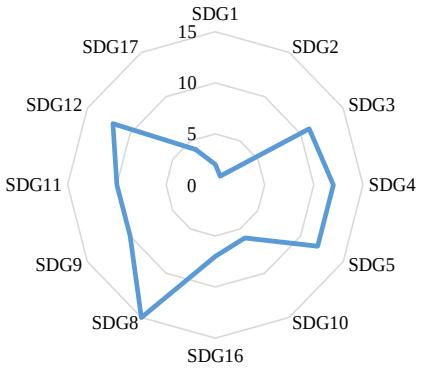
Tab. 3: Chi-square association among impacts and SDGs groups: Norther firms

	Economic SDGs	Social SDGs	Environmental SDGs	Overall SDGs
High	8 (53.3%)	9 (60%)	2 (13.3%)	3 (20%)
Medium	5 (33.3%)	4 (26.6%)	5 (33.3%)	5 (33.3%)
Low	2 (13.3%)	2 (13.3%)	8 (53.3%)	7 (46.6%)
	15	15	15	15

Source: our elaboration

By examining the number of Northern firms that disclose SDG achievements (Fig. 1), it becomes evident that their sustainable efforts are primarily directed towards SDG 4 - *Quality education* (80%) and SDG 5 - *Gender equality* (80%) within the social group, and towards SDG 8 - *Decent work and economic growth* (100%) and SDG 12 - *Responsible consumption and production* (80%) within the economic group.

Fig. 1: Prioritized social and economic SDGs: Norther firms (in number)



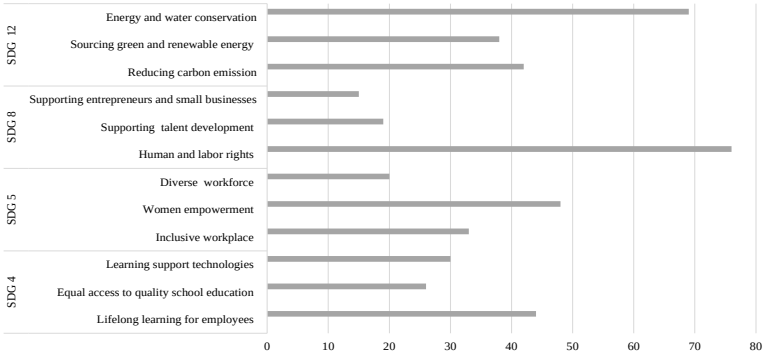
Source: our elaboration

Within these prioritized social SDGs, Figure 2 illustrates that the most frequent actions related to SDG 4 - *Quality education* involve promoting lifelong learning opportunities for employees (44%) by providing access to training courses aimed at enhancing skills and furthering professional development in areas such as sustainability, anti-corruption measures, and human rights. For example, Recordati Spa has implemented a two-year training course for all Group employees to disseminate the principles of the Code of Ethics. This course, available in the languages of subsidiaries, was delivered online, with hard-copy formats distributed for employees without access to digital devices. The course, which included a final assessment of learning, was completed by over three thousand employees. Regarding SDG 5 - *Gender equality,* Northern firms are committed to female empowerment by fostering women's careers in leadership and management (38%). For instance, Hera Spa reports that 34% of managerial positions were held by women in 2021.

Concerning the prioritized economic SDGs, Figure 2 reveals that the most frequent actions related to SDG 8 - *Decent work and economic growth* focus on preserving human rights in the workplace (76%), including improvements in wages and health and safety conditions, and the prohibition of forced labor and child labor. For example, A2A Spa has made Capsule available to workers, a health-pod for self-assessment of physical state, resilience to stress, cellular aging, and dietary habits, with over 2,000 accesses registered.

Regarding SDG 12 - *Responsible consumption and production*, Northern firms are actively involved in waste reduction through prevention, reduction, and reuse policies (e.g., energy and water conservation) (69%). For instance, at Zignago Vetro Spa, recycled glass, which now constitutes almost 50% of the total glass produced by the Group, and packaging recycling are integral parts of the production process.

*Fig. 2: Social and economic SDGs: main actions by Northern firms (in %)**



*More actions are contextually implemented within SDG 4, 5, and 8; thus, the total of the actions exceeds 100% for those specific SDGs.

Source: our elaboration

Table 4 displays the total number of Central-Southern firms for each SDG group along with the corresponding percentage in parentheses. To illustrate, the cells on the far left indicate that Central-Southern firms disclose a low contribution (53.3%) to overall SDGs; however, there is a notable focus on environmental SDGs (47%). The Pearson's Chi-square statistics has a value of 19.726 (df = 4), indicating that the test is significant (p-value <0.01). Thus, the distribution in Table 4 is not random.

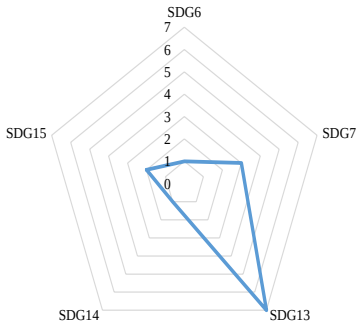
Tab. 4: Chi-square association among the variables: Central-Southern firms

	Economic SDGs	Social SDGs	Environmental SDGs	Overall SDGs
High	2 (13.3%)	2 (13.3%)	7 (47%)	3 (20%)
Medium	4 (27%)	3 (20%)	5 (33.3%)	4 (27%)
Low	9 (60%)	10 (67%)	3 (20%)	8 (53.3%)
	15	15	15	15

Source: our elaboration

By examining the number of Central-Southern firms that disclose SDG achievements (Fig. 3), it becomes evident that their sustainable efforts are primarily directed towards SDG 13 - Climate action (47%) within the environmental group.

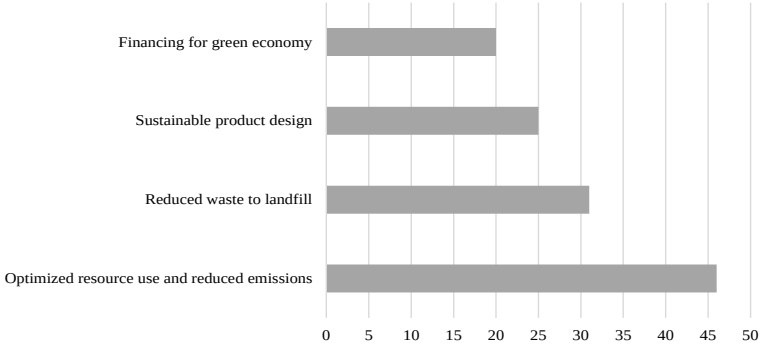
Fig. 3: Prioritized environmental SDGs: Central-Southern firms (in number)



Source: our elaboration

Within these prioritized environmental SDGs, Figure 4 illustrates that the most common actions associated with SDG 13 - Climate action include optimized resource use and reduced emissions (46%) and reduced waste sent to landfills (31%).

*Fig. 4: SDG 13 - Climate action: main actions by Central-Southern firms (in %)**



*More actions are contextually implemented within SDG 13; thus, the total of the actions exceeds 100% for these SDGs.

Source: our elaboration

For example, La Doria Spa has successfully executed the Crystal Project, which aims to decrease packaging surface area and increase the percentage of renewable materials used for Tetra juice packaging. As a result, there have been reductions in CO2 emissions (-14%) and plastic usage (-13%). Similarly, Leonardo Spa has minimized the resources required for product prototyping and testing by implementing digital twins. Furthermore,

the company has diminished waste produced during the manufacturing process through additive manufacturing and has extended product lifespan through predictive maintenance.

5. Discussion

By delving into our research question, findings demonstrate that the geographic localization of businesses at the regional scale is not always a critical variable in achieving the 2030 Agenda in Italy. While many differences in SDG approaches are highlighted at the country level (Rosati and Faria, 2019; van der Waal and Thijssens, 2020; Biglari *et al.*, 2022), this paper suggests less conclusive evidence when narrowing the analysis to within-country scope.

Regarding the overall contribution of Italian firms to the SDGs, the localization in Northern or Central-Southern Italy does not exert any significant impact. In fact, all analyzed firms exhibit limited overall SDG involvement, regardless of their regional macro-area of belonging. This indicates a reduction in the classical North-South gap in Italy, as historic within-country disparities become more nuanced. The limited contribution of Italian firms to the 2030 Agenda aligns with the critical position of Italy, with results for nine out of seventeen sustainable goals lagging behind the average values of the EU (Rapporto ASviS, 2022).

The low contribution of Italian firms to the SDGs can be interpreted as evidence that organizations still perceive sustainable goals as aspirational or forward-looking agendas rather than urgent objectives (Scott and McGill, 2018). This perception may stem from SDGs being seen as pertaining to a macro level, centered around worldwide challenges of sustainable development, which seem distant from corporate sustainability perceived at the micro level (i.e., business level). This disparity is reflected in progress in corporate sustainability not always being aligned with the achievement of the SDGs (Dyllick and Muff, 2015). The latter represent a broad, integrated, and complex development agenda, which are challenging to implement (Allen *et al.*, 2017).

Furthermore, our empirical analysis indicates that few firms provide progress reports towards the stated SDGs and mention the adopted SDGs with quantitative achievements. This evidence suggests a symbolic attitude of Italian firms towards disclosure, consistent with European and global trends (Manes-Rossi and Nicolò, 2022; Calabrese *et al.*, 2022). The symbolic approach is based on a marketing and impression management rationale (Boiral, 2013), driven by increasing pressures from social parties to integrate the SDGs into business strategies and operations, aimed at influencing stakeholder perception of substantive adoption of the 2030 Agenda. Through symbolic compliance with sustainable goals, firms can enhance legitimacy, reputation, and access more resources, without necessarily making costly substantive changes from business-as-usual (Clementino and Perkins, 2021). However, this poses a risk of SDG-washing and cherry-picking practices (Heras-Saizarbitoria *et al.*, 2021) if firms do not undergo significant transformation to accommodate the

ambitions of the 2030 Agenda. Moreover, the scarcity of firms providing progress reports towards the stated SDGs and mentioning the adopted SDGs with quantitative achievements may indicate that Italian companies understand 'why' they should prioritize social, environmental, and economic goals but lack knowledge on 'how' to implement the SDGs (van Tulder *et al.*, 2021). This issue is not exclusive to Italian firms; the absence of strategies for practical SDG implementation in the private sector is among the reasons sustainable development progresses slowly at a global level (Ferreira Caldana *et al.*, 2022).

The neutrality of the regional localization of companies disappears when shifting the focus from the overall contribution of Italian firms to the sustainable goals to prioritized SDGs for firms settled in the different macro-areas of Italy. Thus, the geographic localization of firms at regional scale differentiates the SDGs considered priorities by Italian firms. Specifically, Northern firms address their efforts towards social and economic SDGs, while Central-Southern firms are more oriented towards environmental ones. In this regard, companies are affected by the sustainability policies adopted by the belonging regions. Recent studies, in fact, outline that the Northern regions are more engaged in socio-economic SDGs than other Italian regions, while the Southern regions overperform in environmental SDGs compared to the rest of Italy (ISTAT, 2021; D'Adamo *et al.*, 2021). In other words, the pathway toward the SDGs attainment by regions and that undertaken by local firms are aligned, paving the way to a co-created translation of Agenda's global goals into local aspirations (Ansell *et al.*, 2022). Individual changes, in fact, are not enough to concrete the SDGs but there is a necessity for collective changes involving local actors (Caputo *et al.*, 2020).

The finding that the SDGs priorities vary across geographical localization of firms is in line with Gazzola *et al.* (2020) who state that divergences in the industrialization, economic prosperity, societal structures, and cultural values still emerge among the Italian areas and affect companies' approaches to sustainability issues. Looking at our results at a glance, it emerges that businesses from different regional clusters focus on specific goals at the expense of others within their prioritized SDGs. In particular, Northern firms address their efforts towards SDGs 4 and 5 (social goals) and SDGs 8 and 12 (economic goals), while Central-Southern firms are more oriented to SDG 13 (environmental goals). This aspect could be considered as a form of sustainability metonymy, whereby meeting selected goals is taken to signify conformity to the whole of the 2030 Agenda, disregarding the other ambitions (Siegel and Lima, 2020). On the contrary, the important challenges proposed by the SDGs cannot be dealt with in isolation but should be pursued holistically together to arise the expected benefits due to the integrated and indivisible nature of the sustainable goals (Mio *et al.*, 2020; Dwivedi *et al.*, 2021). Moreover, Northern firms' focus on SDG 4 is not combined with an equal interest in SDG 7 that does not appear among the prioritized goals. This is an interesting finding because SDGs 4 and 7 are considered as synergetic SDGs, which may be problematic because they are key to attaining the rest of the goals and can help in the progression of others (Boar *et al.*, 2021).

6. Conclusions

The paper investigates if and how the geographic localization of firms at the regional scale differentiates the contribution of Italian firms to the SDGs, intended as one of the biggest challenges to be urgently addressed to ensure a future for the planet and humanity. The content analysis of NFDs published by 30 Italian companies, listed on the Italian Stock Exchange and grouped by regional macro-areas, reveals that the geographic localization does not differentiate the overall contribution of Italian firms to the SDGs but affects which SDGs are prioritized by such firms.

From a theoretical viewpoint, this study enriches the body of knowledge on SDGs and on the sustainable actions of companies as it is one of the few studies that focus on the regional location using the firm's lens. In doing so, we respond to the call to better understand the role of businesses as sustainable development agents (Mio *et al.*, 2020), especially through regional comparisons lacking in this research area (D'Adamo *et al.*, 2021). Thus, we try to fill the need for considering sub-national specificities in the literature on sustainable development (Salvia *et al.*, 2019; Liu, 2021) by capturing the connections between firms, belonging territory, and SDGs. Moreover, prior studies determining the presence or absence of SDGs (e.g., Rosati and Faria, 2019; Emma and Jennifer, 2021; van der Waal *et al.*, 2021) are extended because a multi-level scale is employed herein to derive how the firms contribute to SDGs. In addition, an initial picture of main actions implemented at a regional scale is also provided, in line with the need for understanding how companies are working to put the SDGs into action (van der Waal and Thijssens, 2020; Bonfanti *et al.*, 2023).

From a managerial viewpoint, this paper suggests that Italian firms should enhance their commitment to the 2030 Agenda by substantially incorporating the sustainable goals within their corporate culture, business management, and strategic behavior. In this direction, a means for undertaking the disruptive transformations required to achieve the SDGs consists of leveraging and redeploying firms' innovation capabilities to develop new offerings, processes, and business models centered on SDGs (Scherer and Voegtlin, 2020; Gutierrez *et al.*, 2022). Moreover, businesses should adopt a multistakeholder approach because the fast implementation of all the SDGs is beyond the reach of any single firm but needs for the collaboration of all social actors (Palau et at., 2023).

In this logic, a useful proposal could be to foster the establishment of virtuous partnerships between the public, private, and third sectors, e.g., involving research institutes, universities, and firms (Leal Filho *et al.*, 2022). In addition, other possible keys to successfully engage the SDGs are active leadership and the development of core competences at corporate and managerial levels with which to develop supportive strategies that generate social benefits, reduce environmental harm while maintaining profits.

Our paper suggests, in line with Raub and Martin-Rios (2019), to counter "sustainability myopia" and to act locally to identify, ponder and put into action SDG goals. To facilitate this, companies should introduce measurement and control systems that allow them to stay on track and the

SDGs to be achieved; avoid fragmented actions in pursuit of the goals; and act in a timely manner and take corrective actions (Guarini *et al.*, 2022).

From a policymakers' viewpoint, research findings are also interesting for government authorities, especially for regional ones, to define well-targeted interventions for resolving regional gaps and fostering the full adoption of the 2030 Agenda by local businesses in an approach as participatory as possible. Multilevel territorial governance could be a paramount precondition to achieving economic, social, and environmental development objectives even in turbulent times and continuing to take into consideration different cultural settings. The development of new kinds of partnerships taking into consideration the municipal level is also suggested to aid in the SDGs achievement and monitoring. To facilitate this, at a policy level, a possible solution could be to create a system that limits access to public resources in the face of failure to meet targets or comply with regulations.

The limitations of this work suggest avenues for further research. Data was collected only from NFDs, but much non-financial information is included in social and environmental reports provided on a voluntary basis. Thus, a next survey could be performed by interviewing key informants to collect and analyze the primary data. It would be interesting to run cross-country studies for comparing the subnational specificities of Italy in terms of SDGs achievement with those of other countries around the world. Moreover, the present study chooses a limited number of firms, whose NFDs are analyzed, but a wider perspective can be adopted by investigating all firms on the Consob's list to find more robust findings. In the future, it would be interesting to monitor the SDGs adoption over time, extending the temporal horizon herein adopted. Another limitation is related to the content analysis performed manually. In the future, it could be integrated with an automated content analysis integral reading of the documents to deepen the interpretation of the reports. Finally, further connections between geographical localization and SDGs adoption could be captured by grouping the firms not only in regional macro-areas but also in economic sectors, currently heterogeneous. In particular, the focus should be on homogeneous industries, such as banking, which are evenly distributed across Italy. Likewise, it would be interesting to study the relationships between geographic area and other external and internal enablers for SDG implementation.

In conclusion, we invite keeping the research field progressing to train the old and new generations of business leaders in alignment with SDG engagement across all scales. Therefore, more academic research is needed, with a special focus on regional strategies for successful implementation, understanding, and operationalization of the goals in the private sector that seems to be still missing.

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sinergie
italian journal of management

ISSN print 0393-5108
ISSN online 2785-549X
DOI 10.7433/s123.2024.08
pp. 189-213

Original Research Papers

Acceptance and use of digital payments by consumers: an empirical analysis in Italy

Received
6th March 2023
Revised
28th September 2023
Accepted
20th December 2023

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Abstract

Framing of the research. *Several governments have introduced policies to foster the usage of digital payments by consumers, with the goal of curbing tax evasion. Nevertheless, cash is still predominant. This raises questions about the factors that can promote the usage of digital payments by consumers.*

Purpose of the paper. *This paper aims at investigating the factors affecting the adoption of digital payments by Italian consumers, extending the unified theory of acceptance and use of technology in a consumer context (UTAUT2) with three constructs that are relevant when analyzing this topic, namely the role of government incentives, the concerns related to privacy, and the degree of aversion towards tax evasion.*

Methodology. *To empirically assess the proposed research model, we gathered data in Italy through a web-based survey and analyzed them using Partial Least Squares-Structural Equation Modeling.*

Results. *Findings confirm the UTAUT2 model, except for price value, which is found to be insignificant. Government incentives and tax evasion aversion have a significant positive impact on the behavioral intention to adopt digital payments, whereas privacy concerns have a significant negative effect.*

Research limitations. *The main limitation of this study concerns data gathering, as it was conducted using the Computer-Assisted Web Interviewing methodology, which targets consumers that are already familiar with digital instruments.*

Practical implications. *The paper highlights the factors that both digital payment providers and public institutions may leverage to foster the adoption of digital payments by consumers.*

Originality of the paper. *To the best of our knowledge, this study is unique as it examines the adoption of digital payments by Italian consumers, extending the framework to prepaid, credit, and debit cards, instead of considering mobile payments alone.*

Key words: *digital payments; consumer behavior; UTAUT2; Italy; government incentives*

1. Introduction

Digital payments are gaining popularity in both scientific and empirical domains. In fact, not only the usage of digital payments is growing worldwide (Worldpay from FIS, 2023), but also the number of articles analyzing the topic significantly increased over the past decade (see Appendix A). At

the same time, several governments have introduced policies to foster the adoption of digital payments by consumers, with the main goal of curbing tax evasion (Sung *et al.*, 2017). The underlying assumption is that cash payments enable sellers to easily hide the transaction history, thereby facilitating underreporting of revenues. In contrast, digital payments are traceable and make evasion more difficult to accomplish (Immordino and Russo, 2018) by increasing the perceived likelihood of detection (Madzharova, 2020). Moreover, digital payments enable innovative services (Zhang *et al.*, 2019) otherwise impossible to deliver (e.g. smart mobility services), and foster the diffusion of e-commerce (Gomez-Herrera *et al.*, 2014; International Chamber Of Commerce, 2020).

Despite all these potential benefits, cash is still predominant in most economies (Worldpay from FIS, 2023). For instance, in the euro area, cash accounted for a large part of the transactions at the Point Of Sale (POS) in 2021 - namely 59% in terms of number and 42% in terms of value of transactions (European Central Bank, 2022). The same is true for Italy: in 2021, cash accounted for 69% of total number of transactions at POS and 49% of their total value (European Central Bank, 2022).

For these reasons, it is interesting to investigate which factors drive or hinder the adoption and the usage of digital payments by consumers. To tackle this issue, literature largely exploited the unified theory of acceptance and use of technology in a consumer context (UTAUT2), formulated by Venkatesh *et al.* (2012). For instance, Morosan and DeFranco (2016) uses UTAUT2 to investigate the consumers' intention to use mobile payment in hotels in the United States, Al-Okaily *et al.* (2020) expand UTAUT2 to study the adoption of mobile payment in Jordan while Migliore *et al.* (2022) use a similar framework to compare mobile payment adoption in China and Italy. Actually, most of the studies applying UTATU2 to the payment industry are focused on mobile payment methods (Patil *et al.*, 2018). However, these methods represent just a fraction of digital payments, a category which includes card payments as well. This leaves an important gap to be filled since most of governmental policies target digital payments in general, i.e., they include credit or debit cards as well[1]. Therefore, research on the drivers to the adoption of digital payments could provide governments with useful insights on how these policies can be designed, if the framework is extended to include card payments as well.

From a theoretical perspective, we resorted to UTAUT2 because it has been the preferred theoretical lens to investigate mobile payments, especially in recent years (Al-Okaily *et al.*, 2020; Migliore *et al.*, 2022; Morosan and DeFranco, 2016; Santosa *et al.*, 2021; Sivathanu, 2019; Slade *et al.*, 2014). Moreover, it is one of the most comprehensive Information Systems (IS) adoption theories.

However, UTAUT2 is formulated as a micro level theory, i.e., a theory focused on narrow constrained set of phenomena and constructs

[1] For instance, the Tax Incentives for Electronically Traceable Payments (TIETP) introduced in South Korea (Sung *et al.*, 2017); the Piano Italia Cashless introduced in Italy (see Section 3); the policies introduced in Greece with law 4446/2016 (Danchev *et al.*, 2020).

(Tamilmani *et al.*, 2021; Venkatesh *et al.*, 2016). As such, it lacks formulations of research models at the meso-level (Venkatesh *et al.*, 2016), allowing to explore the pivotal role of the context in which digital payments are accomplished by consumers. To fill this gap, we aim extending UTAUT2 with two contextual factors: (1) the role of government incentives, which provide monetary inducements for the adoption of digital payments and could therefore enhance their usage (as suggested by Sivathanu, 2019); (2) the degree of aversion towards tax evasion, which could encourage consumers to adopt digital payments (Immordino and Russo, 2018).

Also, we added a construct to measure a specific feature of the technology under investigation, namely the concerns related to privacy (Stewart and Segars, 2002; Zerbini *et al.*, 2022), which could prevent people from adopting a technology as it has been already demonstrate by similar studies (Soodan and Rana, 2020).

Our paper aims to extend UTAUT2 with the above-mentioned three factors, to better understand how to foster digital payments in general, without limiting the analysis to mobile payment only. In other words, the following research question is addressed: "Which are the drivers to consumers' adoption of digital payments in Italy?". We test our model in the Italian context because it is of particular interest, as the infrastructure for the acceptance of digital payments is well developed and aligned with the rest of the European Union (EU) while the actual usage by consumers is far below the EU average (European Central Bank, 2021) - See Section 3.

Our results confirm the UTAUT2 model, with the only exception of price value, which plays no role. Also, both government incentives and tax evasion aversion are drivers to the adoption of digital payments by consumers, while privacy concerns represent a barrier. Thus, our study highlights the factors that both digital payment providers and public institution can leverage in order to promote digital payments.

The reminder of the paper is organized as follows. Section 2 describes the theoretical background. Section 3 shows the empirical context. Section 4 summarizes the research model together with the hypotheses. In section 5 we present the research methodology. Section 6 and 7 provide, respectively, the main findings and discussion. Finally, Section 8 presents the limitations and suggestions for future research.

2. Theoretical background

Our analysis contributes to the field of research on the adoption of digital payments by consumers. In this paragraph, we first present the main theories on the acceptance of technologies. Then, we analyze the literature on digital payments.

2.1 Adoption theories

The individual acceptance and adoption of IS has been widely investigated over the past decades and a number of popular theoretical models have been developed and tested (Morosan and DeFranco, 2016;

Slade *et al.*, 2014; Venkatesh *et al.*, 2003). The most popular models are the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), the Theory of Planned Behavior (TPB) (Ajzen, 1991), the Technology Acceptance Model (TAM) (Davis, 1985, 1989; Davis *et al.*, 1989), the Motivational Model (MM) (Davis *et al.*, 1992), the Combined TAM and TPB (C-TAM-TPB) (Taylor and Todd, 1995), the Model of PC Utilization (MPCU) (Thompson *et al.*, 1991), the Innovation Diffusion Theory (IDT) (Moore and Benbasat, 1991), and the Social Cognitive Theory (SCT) (Bandura, 1986).

Given the fragmentation of research on individual adoption of IS, Venkatesh *et al.* (2003) analyze the above-mentioned eight theories with the goal of formulating a unified theoretical model that could capture the essential elements of the models. As a result, the Unified Theory of Acceptance and Use of Technology (UTAUT) was formulated. Since UTAUT was initially developed for corporate settings, Venkatesh *et al.* (2012) proposed a revision of the theory to investigate technology adoption by consumers. The new theory, called UTAUT2, has become the preferred theoretical lens to investigate the adoption of digital and mobile payments (e.g. Al-Okaily *et al.*, 2020; Migliore *et al.*, 2022; Morosan and DeFranco, 2016; Santosa *et al.*, 2021; Sivathanu, 2019; Slade *et al.*, 2014).

UTAUT2 identifies seven factors that are expected to influence the behavioral intention to adopt a technology and its actual usage. These factors are performance expectancy, effort expectancy, social influence, facilitating conditions, price value, hedonic motivation, and habits. The first four factors were included in the original formulation of the theory (UTAUT). More specifically, performance expectancy is defined as "the degree to which using a technology will provide benefits to consumers in performing certain activities" (Venkatesh *et al.*, 2012, p. 159); effort expectancy indicates "the degree of ease associated with consumers' use of technology" (Venkatesh *et al.*, 2012, p. 159); social influence refers to "the extent to which consumers perceive that important others (e.g. family and friends) believe they should use a particular technology" (Venkatesh *et al.*, 2012, p. 159); facilitating conditions are the "consumers' perceptions of the resources and support available to perform a behavior" (Venkatesh *et al.*, 2012, p. 159).

The last three factors, instead, have been added by the authors in the new formulation of 2012, where hedonic motivation is defined as "the fun or pleasure derived from using a technology" (Venkatesh *et al.*, 2012, p. 161); price value is measured as "consumers' cognitive tradeoff between the perceived benefits of the applications and the monetary cost for using them" (Venkatesh *et al.*, 2012, p. 161); habits are defined as a self-reported perception, i.e., "the extent to which an individual believes the behavior to be automatic" (Venkatesh *et al.*, 2012, p. 161).

Moreover, as pointed out by Tamilmani *et al.* (2021) and Venkatesh *et al.* (2016), the UTAUT2 is formulated with "consumers" as focal point, meaning that it is focused on a narrow constrained set of phenomena. In other words, it is formulated at the micro-level. As a consequence, both Tamilmani *et al.* (2021) and Venkatesh *et al.* (2016) suggest that the theory could be enriched by adding contextual factors at a higher level

of hierarchy, i.e. to add factors that allow a meso-level formulation. For this reason, we added two variables that reflect the context of the Italian payment industry and that can have, ultimately, an impact on consumers' behavior. These factors are the role of government incentives (or subsidies) and tax evasion aversion (see Section 4.2 for further discussion).

Finally, UTAUT2 does not include a variable that has becoming more and more important with the diffusion of new digital technology, namely the concerns for one's privacy. Since 2012, when UTAUT2 was first developed, the diffusion of new digital technologies has dramatically increased (OECD, 2020). With the emergence of data-rich technologies, e.g., the Internet of Things, big data analytics, and artificial intelligence as well as changes in the data-sharing behavior of consumers, the amount of personal data generated and shared has increased (OECD, 2020). At the same time, because of high-profile data breaches, individuals are becoming increasingly aware and concerned about digital risks (OECD, 2020). As a consequence, the need to safeguard one's privacy has become pressing to the extent that it could be a deterrent to the adoption of a technology (OECD, 2017; Soodan and Rana, 2020). For these reasons, we believe that adding the factor privacy concern will improve the explanatory power of UTAUT2.

2.2 Digital payment methods

Digital payments are defined as transactions made for the purchase of goods or services made by digital means only (Sahi *et al.*, 2021; Sivathanu, 2019). More specifically, we include in this definition payment cards, which are defined by the European Central Bank (ECB)[2] as "payment instruments, which are based on the rules of a card scheme, used to withdraw or place cash and/or enable a transfer of value at the request of the payer (via the payee) or the payee in respect of an end-user account linked to the card", i.e., instruments that enable holders to pay sellers directly at the point of sale (in-store payments) or over the internet (e-commerce). Payment cards can be credit cards, debit cards, or prepaid cards (e-money). The definition of digital payments also includes mobile payment, which is defined by the ECB[3] as "a payment where a mobile device is used at least for the initiation of the payment order and potentially also for the transfer of funds". The definition does not include either cheques, since they are paper-based instruments, or bank transfer and direct debits, since their usage is comparably low in B2C transactions (European Central Bank, 2020).

Dahlberg *et al.* (2008) and Dahlberg *et al.* (2015) review the literature on mobile payment. The former analyze the literature published from 1999 to 2006, finding 73 articles. The latter integrate the study by adding the 87 articles published from 2007 to 2014. They both find that the literature is focused mainly on adoption by consumers and technological aspects, such as security and trust. Another literature review on payment instruments

[2] For more information see: https://www.ecb.europa.eu/services/glossary/html/glossp.en.html

[3] For more information see: https://www.ecb.europa.eu/services/glossary/html/glossm.en.html#598

is the one of Khando *et al.* (2022), who analyze the research on the main digital payment methods, finding that the most analyzed category is indeed mobile payment.

Also, Patil *et al.* (2017) specifically review the research on adoption of digital and mobile payment. The authors analyze 21 contributions finding that the most applied theories are the TAM - both original and extended - and UTAUT/UTAUT2. Also, the 21 papers are all focused on mobile payment.

What emerges is a focus on the adoption of mobile payment only. As examples, Morosan and DeFranco (2016) analyze the topic within hospitals in the United States. The authors apply UTAUT2 and find that performance expectancy is the main driver to the behavioral intention to adopt the technology, while the effect of hedonic motivation, habit and social influence is weaker.

Oliveira *et al.* (2016) combine UTAUT2 and the DOI theory, to analyze adoption and intention to recommend mobile payment among consumers in Portugal. Also, Al-Okaily *et al.* (2020) study the adoption of mobile payment in Jordan, by adding four additional factors to UTAUT2, namely awareness, security, privacy and culture. Finally, Migliore *et al.* (2022) integrate UTAUT2 and Innovation Resistance Theory (IRT) to investigate the differences in adoption between China and Italy. The authors find that the tradition barrier is the only significant impediment to mobile payment adoption.

To sum up, the literature on payment instruments is focused on mobile payment only, while other methods - like payment cards - are largely neglected. However, investigating digital payments in general - i.e. adding cards to the framework - is of practical relevance. Indeed, the majority of governmental policies that aim to foster digital payments target the entire category, that is, both cards and mobile payments. For this reason, research that highlight which factors drive or hinder the adoption of digital payments in general can provide useful insights to governments, allowing to improve the efficiency of the policies.

3. Empirical context

We have studied digital payments in the context of Italian consumers because the Italian case is of particular interest for several reasons. First, the infrastructure for the acceptance of digital payments is well developed, as it consisted of 60,647 POS terminals per million inhabitants, significantly above European Union (EU) average (32,663), and 1.99 payment cards per capita, slightly above EU average (1.92), as of 2020 (European Central Bank, 2021). Nevertheless, digital payments are underused. In 2020 Italian citizens made on average 80.7 transactions with payment cards, well below the EU average (145.8) (European Central Bank, 2021). Also, as shown in Section 1, cash is still widespread. This raises questions on the mismatch between the potential and actual usage of digital payments in Italy.

In addition, in 2019 the Italian government introduced the Piano Italia Cashless policy. The policy includes both incentives and deterrents that

target both consumers and retailers, with the goal of encouraging the usage of digital payments, in order to reduce cash usage and, eventually, tax evasion. For our analysis, we will focus on the incentives granted to consumers, namely the so-called Cashback and a receipt lottery.

The Cashback incentive granted consumers a 10% reimbursement on the purchase of goods for transactions made in stores with payment cards. It was active for two periods: from December 8th 2020 to December 31st 2020 and from January 1st 2021 to June 30th 2021[4]. The second incentive is a receipt lottery introduced on February 1st 2021 and still ongoing. It is a lottery where the ticket number is incorporated in purchase receipts[5].

Finally, from a theoretical perspective, in their review of the literature, Patil *et al.* (2017) suggest that future research should focus on Western countries with high cash usage, and Italy fits the description.

4. Research model and hypotheses

We resorted to UTAUT2 because it has become the preferred theoretical lens to investigate the adoption of digital and mobile payments, thereby suiting the goal of our paper (e.g. Al-Okaily *et al.*, 2020; Migliore *et al.*, 2022; Morosan and DeFranco, 2016; Santosa *et al.*, 2021; Sivathanu, 2019; Slade *et al.*, 2014).

In the present paragraph, we present the hypotheses of the research model, distinguishing between the hypotheses derived from UTAUT2 and the proposed new hypotheses. The investigated variables are the UTAUT2 factors, as defined in Section 2.1.

4.1 UTAUT2 hypotheses

As shown in Section 2.1, UTAUT2 investigates the factors that influence the behavioral intention to adopt a technology and its actual usage. Such factors are performance expectancy, effort expectancy, social influence, facilitating conditions, price value, hedonic motivation, and habits.

Performance expectancy refers to the benefits provided by the technology: the higher the perceived benefits, the higher the likelihood that a consumer will adopt that technology (Venkatesh *et al.*, 2012). The majority of studies on mobile payment adoption have found performance expectancy to be one of the most significant drivers of consumer's behavioral intention to adopt mobile payment (Patil *et al.*, 2017). Accordingly, it can be proposed that the utilitarian benefits provided by digital payments are expected to foster adoption, as they offer a convenient way to make a transaction. Namely:

H1: Performance expectancy positively affects the behavioral intention to adopt digital payments.

[4] For more information see https://www.cashlessitalia.it/cashback.html

[5] For more information see https://www.lotteriadegliscontrini.gov.it/portale/home

Effort expectancy relates to the work that the consumer expect to be necessary to use the technology (Venkatesh *et al.*, 2012). The harder the effort, the lower should be the adoption. Conversely, if less effort is required, then the consumer will have stronger intention to use any kind of technology (Sivathanu, 2019). More specifically, it can be proposed that if consumers find using digital payment effortless, they will be more likely to adopt the technology (Santosa *et al.*, 2021). Accordingly, it is proposed that:

H2: Effort expectancy positively affects the behavioral intention to adopt digital payments.

Social influence refers to the impact that the social network - e.g. family and friends - has on consumers' decision to adopt the technology (Venkatesh *et al.*, 2012). Consumers tend to have a favorable image of a technology if they believe that they can gain social status by using it (Venkatesh and Davis, 2000; Venkatesh and Morris, 2000). Among others, (Sivathanu, 2019) provides evidence that social influence has a positive impact on the behavioral intention to adopt digital payments, while Migliore *et al.* (2022) and Yang *et al.* (2012) found that social influence is an antecedent of the behavioral intention to adopt mobile payments. Thus, based on the existing literature, it is proposed that:

H3: Social influence positively affects the behavioral intention to adopt digital payments.

Facilitating conditions indicate the resources and support that the consumer can rely on when using a new technology (Venkatesh *et al.*, 2012). Using mobile payments requires both consumers to have certain skills and qualities, e.g., to be confident in their ability to use a smartphone for making payments, and the availability of relevant infrastructure, e.g., reliable internet coverage (Migliore *et al.*, 2022). The same applies to the usage of payment cards as well. Consequently, it is proposed that:

H4: Facilitating conditions positively affect the behavioral intention to adopt digital payments.

Hedonic motivation represents the pleasure and fun that a consumer experience by using a technology (Venkatesh *et al.*, 2012). Consumers are expected to enjoy using a technology when it is pleasurable and fun to use (Lee, 2009). Moreover, over time the enjoyment and emotional aspects associated with purchases gained significance also in the digital context (Zerbini *et al.*, 2022). Consistently, it can be proposed that if consumers expect digital payment to be enjoyable to use, they will be more likely to adopt it:

H5: Hedonic motivation positively affects the behavioral intention to adopt digital payments.

Price value refers to the comparison between the perceived benefits of the technology and its costs (Venkatesh *et al.*, 2012). The adoption of a technology is expected to increase when its perceived benefits are greater and the perceived monetary cost is low (Migliore *et al.*, 2022). Consistently, it can be proposed that if consumers perceive that digital payment providers offer good price value, they will be more likely to adopt the technology (Santosa *et al.*, 2021):

H6: Price value positively affects the behavioral intention to adopt digital payments.

Habits are defined as a self-reported perception, i.e., "the extent to which an individual believes the behavior to be automatic" (Venkatesh *et al.*, 2012). Habits are expected to have a positive impact on the intention to use a technology, including for digital payments. Thus, it is proposed that:

H7: Habits positively affect the behavioral intention to adopt digital payments.

Finally, behavioral intention indicates the consumer willingness to adopt digital payments and it is assumed to be an antecedent of usage behavior of digital payments, as already stated by previous studies (Venkatesh *et al.*, 2003, 2012). We therefore propose the following hypothesis:

*H8: Behavioral intention positively affects the digital payment*s use

4.2 Extended model hypotheses

UTAUT2 does not include some factors that might be of interest when analyzing the adoption of digital payments, namely (i) the role of government incentives, (ii) concerns related to privacy, and (iii) the degree of aversion towards tax evasion.

Government incentives refers to financial motivations for people to take certain actions. They can also be defined as subsidies, i.e. "government assistance that allows consumers to purchase goods and services at prices lower than those offered" (Schwartz and Clements, 1999, p. 120). The Piano Italia Cashless introduced in Italy falls under this definition. We decided to include government incentives since they are measures specifically designed to affect consumers' behavior and therefore should have an impact on the acceptance and use of digital payments. Moreover, previous research suggested the need to investigate the impact of government support (Sivathanu, 2019). The formative construct "government incentives" measures the participation to both the Cashback initiative and the receipt lottery. Since the two programs provide monetary incentives to adopt digital payments, it can be proposed that:

H9: Government incentives positively affect the behavioral intention to adopt digital payments.

Privacy concerns are defined as "concerns about possible loss of privacy as a result of a voluntary or surreptitious information disclosure" following

a transaction made through a digital payment instrument (Dinev and Hart, 2005). The importance of protecting one's privacy is becoming ever more relevant, especially when adopting digital technologies (Stewart and Segars, 2002; Zerbini *et al.*, 2022). Privacy concerns may lead consumers to safeguarding behaviors that may negatively affect their engagement with a technology (Soodan and Rana, 2020; Stewart and Segars, 2002), and should therefore be included in the proposed extended model as specified in the following hypothesis:

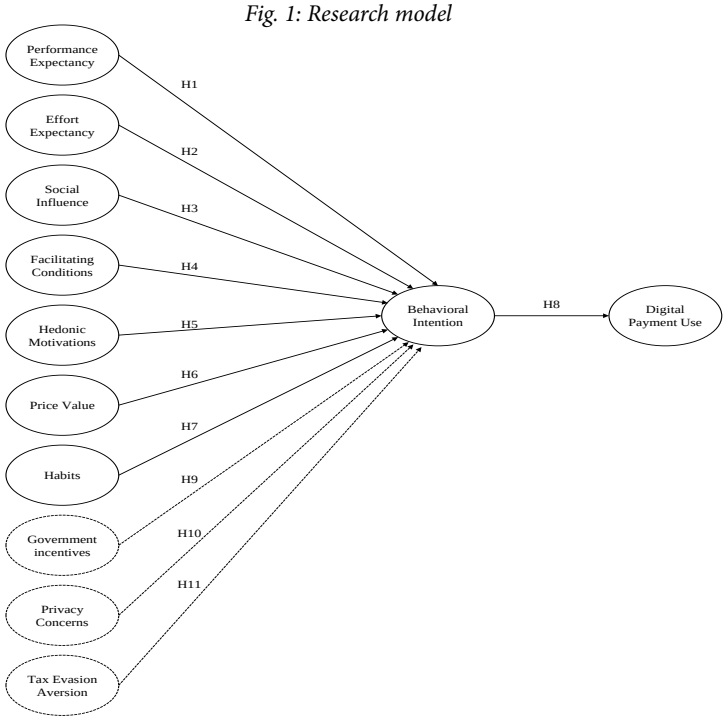
H10: Privacy concerns negatively affect the behavioral intention to adopt digital payments.

Tax evasion aversion indicates the aversion of a consumer towards tax evasion. Digital payment methods are traceable and therefore make tax evasion more complicated (Immordino and Russo, 2018). As a consequence, a buyer who is highly concerned about the negative externalities brought by tax evasion may choose to pay with digital means only, to prevent the seller from evading taxes. For this reason, we decided to include the following hypothesis in the model:

H11: Tax evasion aversion positively affects the behavioral intention to adopt digital payments.

Fig. 1 shows the research model with the proposed hypotheses.

Fig. 1: Research model



Source: authors' elaboration

5. Research methodology

The target population is composed of adult (18+) Italian consumers. To collect the data, we designed a questionnaire that included constructs and scales derived from previous studies (Dinev and Hart, 2005; Venkatesh *et al.*, 2003, 2012) - see Appendix B for further details. We used a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree" to measure the various items.

The questionnaire was administered in Italian. Since the scales drawn from the literature were in English, the initial questionnaire was developed in English and then translated into Italian by the main author. The Italian version was then double-checked by Italian-speaking researchers in order to check the consistency and the comprehensiveness of the various questions.

There were two further assessments of the validity of the questionnaire. First, the questionnaire was pre-tested with the help of Ipsos, a firm specialized in market research. The second test was conducted with the main players of the Italian payment sector[6]. Based on the feedback, the wording of some questions was changed, to better reflect the context of the study.

The questionnaire was administered by Ipsos. To ensure representativeness, we resorted to quota controls. More specifically, the sampling was conducted by Ipsos using a software that selects potential respondents who match the target using interactive selection algorithms based on marginal and crossed quotas.

The survey was carried out using Computer-Assisted Web Interviewing (CAWI) methodology, which is not uncommon in the literature (e.g. Migliore *et al.*, 2022; Oliveira *et al.*, 2016). Thus, the population of reference is Italian citizens, aged from 18 to 75. The online survey was conducted between November 2021 and December 2021, and a total of 1,894 answers were gathered.

All factors were measured through reflective indicators, with the only exceptions of use behavior and government incentives. Digital payment use was measured as a formative compositive index of frequency of digital payments use, as suggested by Venkatesh *et al.* (2012). Respondents were provided with a list of the five main digital payment method types, namely prepaid cards, debits cards, credit cards, mobile wallets, and mobile payment apps, and were asked to indicate their usage frequency for each instrument. The anchors of the 5-point Likert scale ranged from "never" to "always". The construct government incentives were measured as a

[6] The questionnaire was sent for a preliminary assessment to the following companies: Agos, American Express, Banca Cambiano, Banca Mediolanum, Banca di Asti, Banca Popolare di Sondrio, Banco BPM, Bancomat, BNL - Gruppo BNP Paribas, Capgemini, Cassa Centrale Banca, Custom, Deloitte, Deutsche Bank, Edenred Italia, Edison, Enel X Global Retail, EY, HYPE, Intesa Sanpaolo, ING, Klarna, LIS Holding, Mastercard, Mooney, Nexi, N&TS GROUP, Opentech.com, PAX Italia, Pay Reply, PayDo, PayPal, PayPlug, PostePay, PwC, Q8, Scalapay, Sinergia, Soldo, Software AG, TeamSystem, UNGUESS, UniCredit, UnipolSai, Visa, Wolters Kluwer Tax&Accounting, Zucchetti.

formative compositive index of frequency of receipt lottery use and the participation to the Cashback program. The frequency of receipt lottery use was measured using a 5-point Likert scale with anchors ranging from "never" to "always", whereas the participation to the Cashback initiative was measured through a dummy variable equal to 1 if the respondents had taken part in the incentives, 0 otherwise.

6. Results

In this paragraph, we first present descriptive statistic and, then, the results of the proposed research model.

6.1 Descriptive statistics

Table 1 provide descriptive statistics about the sample. 51.46% of the respondents to the survey are female, while the remaining 48.54% is male. This distribution is in line with the one of the population of reference: of the Italians aged 18 to 75, 50.4% is female[7]. Also, the majority of the respondents - 54.55% - is older than 45, while respondents younger than 33 years old account for 25.40% of the total sample. Again, this is in line with the Italian population.

Moving to education, 40.05% have a lower degree of education, while 17.75% are highly educated. Finally, regarding the place of residence, the majority of the respondents live in towns with less than 30,000 inhabitants and 23.54% live in bigger cities.

Tab. 1: Descriptive statistics

	Share of total sample
Gender	
Male	48.54%
Female	51.46%
Age	
18-24	9.03%
25-34	16.37%
35-44	20.05%
45-54	17.5%
55-75	37.05%
Education	
Low	40.05%
Medium	42.2%
High	17.75%
Place of residence (number of inhabitants)	
< 30,000	54.91%
30,000 - 100,000	21.55%
> 100,000	23.54%

Source: authors' elaboration

[7] http://dati.istat.it, accessed on October 23th, 2023.

6.2 Measurement and structural model

We first checked the normality of data by testing the skewness and kurtosis *of* each indicator. The p-values of the tests were all equal to 0.00, meaning that the null hypothesis of normal distribution is rejected. Data were then analyzed using Partial Least Squares (PLS) - Structural Equation Modeling (SEM), which is "a causal modeling approach aimed at maximizing the explained variance of the dependent latent constructs" (Hair *et al.*, 2011). We resorted to PLS-SEM since it is usually suggested when: (i) the research goal is extending an existing structural theory; (ii) the structural model includes formative constructs; (iii) the structural model is complex, i.e., it includes many constructs; and (iv) data are nonnormal to some extent (Hair *et al.*, 2011). Stata17 software was used to run the statistical analyses, together with the plssem package (Venturini and Mehmetoglu, 2019).

Following Hamdollah and Purya (2016), results are provided using the two-step approach: first the measurement model is evaluated and then the structural model is examined.

The first step is to evaluate the measurement model's reliability and validity (Hair *et al.*, 2011). Reflective constructs have been assessed with respect to their reliability and validity. Indicator reliability was assessed by verifying that the factor loadings are all greater than 0.7 (Hair *et al.*, 2011). Since we found a factor loading smaller than 0.7 for the item FC_3, we decided to exclude the variable from the analysis and to revert to two-item measurement for the latent variable facilitating conditions. Construct reliability was tested by computing the Cronbach's alpha, which exceeded the minimum threshold of 0.7 for every construct (Hamdollah and Purya, 2016). Convergent validity was tested using the average variance extracted (AVE). The AVE should exceed the minimum threshold of 0.5, indicating that the latent variable explains at least half of the variance of its indicators (Hamdollah and Purya, 2016). Results are shown in Tab. 2.

Discriminant validity was tested by using two measures. First, we checked that an indicator's loading with its associated latent variable is higher than the cross-loadings (Hair *et al.*, 2011). Then, the Fornell-Larcker criterion (Fornell and Larcker, 1981) was applied, testing whether the AVE of each latent construct is higher than the latent construct's squared correlation with the other latent constructs (results are shown in Tab. 3). Government incentive and digital payment use were measured using two and five formative indicators, respectively, and had weights between 0.26 and 0.86, and 0.20 and 0.53. Results are shown in Tab. 4.

Tab. 2: Descriptive statistics and indicators for the evaluation of the measurement reflective model

Construct	Item	Mean	Standard deviation	Cronbach's alpha	Outer loadings	AVE
Performance expectancy (PE)	PE_1	3.965	0.911	0.776	0.794	0.690
	PE_2	3.883	0.994		0.857	
	PE_3	3.856	0.903		0.840	
Effort expectancy (EE)	EE_1	3.908	0.880	0.790	0.821	0.703
	EE_2	3.978	0.869		0.841	
	EE_3	3.990	0.838		0.854	
Social influence (SI)	SI_1	3.501	0.967	0.748	0.767	0.666
	SI_2	3.365	1.018		0.870	
	SI_3	3.261	1.076		0.807	
Facilitating conditions (FC)	FC_1	3.861	0.910	0.707	0.866	0.773
	FC_2	3.956	0.866		0.892	
Hedonic motivation (HM)	HM_1	3.510	1.000	0.821	0.841	0.737
	HM_2	3.478	1.008		0.854	
	HM_3	3.659	0.944		0.880	
Price value (PV)	PV_1	3.565	0.961	0.771	0.804	0.684
	PV_2	3.531	1.023		0.844	
	PV_3	3.417	1.056		0.833	
Habits (HA)	HA_1	3.503	1.102	0.814	0.827	0.730
	HA_2	3.843	0.941		0.866	
	HA_3	3.844	0.994		0.869	
Privacy concerns (PC)	PC_1	3.254	1.045	0.750	0.796	0.651
	PC_2	3.319	1.002		0.754	
	PC_3	3.100	1.046		0.866	
Tax evasion aversion (TEA)	TEA_1	4.130	0.963	0.825	0.833	0.741
	TEA_2	4.097	0.934		0.860	
	TEA_3	4.126	0.952		0.888	
Behavioral intention (BI)	BI_1	3.640	1.090	0.819	0.813	0.734
	BI_2	3.954	0.903		0.884	
	BI_3	4.014	0.911		0.872	

Source: authors' elaboration

Tab. 3: Fornell-Larcker criterion for discriminant validity

	PE	EE	SI	FC	HM	PV	HA	PC	TEA	BI
PE	**0.690**									
EE	0.486	**0.703**								
SI	0.267	0.148	**0.666**							
FC	0.388	0.544	0.134	**0.773**						
HM	0.453	0.291	0.306	0.233	**0.737**					
PV	0.392	0.299	0.238	0.263	0.387	**0.684**				
HA	0.603	0.459	0.309	0.381	0.470	0.388	**0.730**			
PC	0.019	0.015	0.001	0.007	0.001	0.011	0.029	**0.651**		
TEA	0.335	0.280	0.111	0.243	0.158	0.162	0.255	0.007	**0.741**	
BI	0.629	0.448	0.279	0.386	0.431	0.361	0.656	0.025	0.339	**0.734**

Source: authors' elaboration. AVE is shown in bold on the main diagonal and squared correlations below the main diagonal.

Tab. 4: Descriptive statistics and outer weights for formative constructs

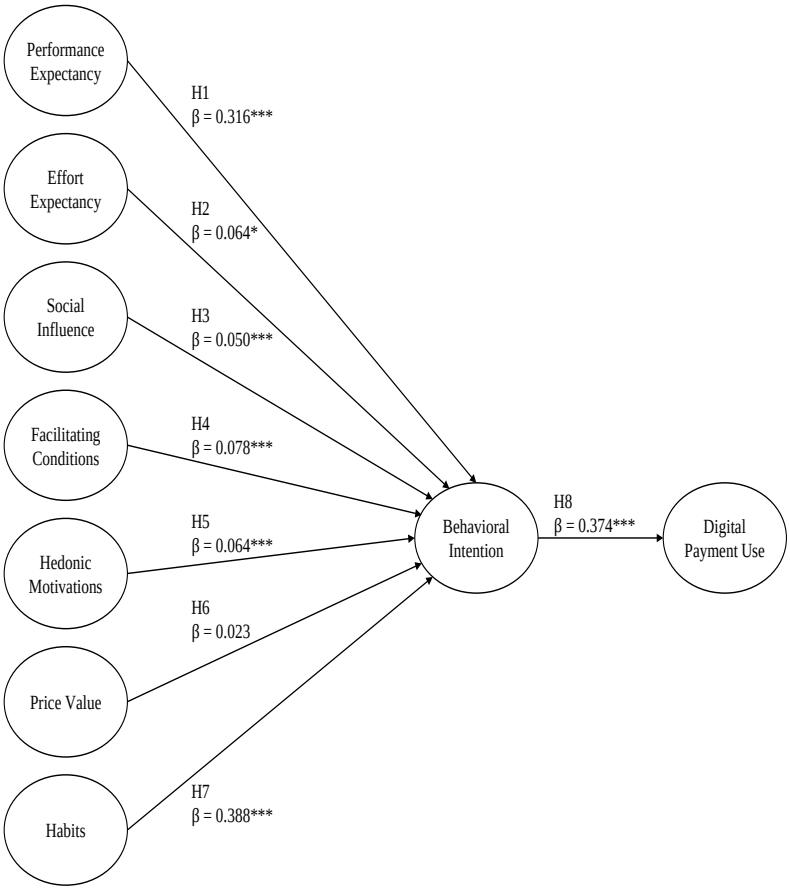
Construct	Item	Mean	Standard deviation	Outer weights
Government incentives	Cashback	0.468	0.499	0.859
	Lott_use	1.140	1.674	0.262
Digital payment use	UB_prepaid	1.904	1.766	0.384
	UB_debit	2.315	1.914	0.520
	UB_credit	1.417	1.795	0.543
	UB_wallet	0.351	1.030	0.203
	UB_mobile_app	1.316	1.704	0.340

Source: authors' elaboration

The measurement model was found to be reliable and valid, and therefore the path analysis was carried out. We ran two separate models: the first one to the support for the baseline UTAUT2 model (direct effects only) and the second one for the proposed extended model. We first tested for multicollinearity by computing the Variance Inflation Factors (VIFs), which were found to be less than the threshold of 5 (Venkatesh *et al.*, 2012) in both models, thereby suggesting that multicollinearity was not a major issue in our study.

As shown in Fig. 2 the main structure of UTAUT2 was confirmed, with the only exception of price value, which was surprisingly found to be insignificant. Similarly, when the three proposed additional constructs were added to the model, significant path coefficients were found with all latent variables, with the only exception of price value (Fig. 3). Results are shown in Tab. 5 as well.

Fig. 2: Structural model results: UTAUT2 model



Source: authors' elaboration. *p < 0.05; **p < 0.01; ***p < 0.001; all other correlations are insignificant

Fig. 3: Structural model results: extended model, new constructs are shown as dotted lines

Source: authors' elaboration. *p < 0.05; **p < 0.01; ***p < 0.001; all other correlations are insignificant.

Tab. 5: Structural model results, UTAUT2 and extended model

	UTAUT2		Extended model	
Hypothesis	Path coeff.	Decision	Path coeff.	Decision
H1: Performance expectancy positively affects the behavioral intention to adopt digital payments.	0.316***	Supported	0.263***	Supported
H2: Effort expectancy positively affects the behavioral intention to adopt digital payments.	0.064**	Supported	0.045*	Supported
H3: Social influence positively affects the behavioral intention to adopt digital payments.	0.050***	Supported	0.049**	Supported
H4: Facilitating conditions positively affect the behavioral intention to adopt digital payments.	0.078***	Supported	0.061**	Supported
H5: Hedonic motivation positively affects the behavioral intention to adopt digital payments.	0.064***	Supported	0.077***	Supported
H6: Price value positively affects the behavioral intention to adopt digital payments.	0.023	Not supported	0.019	Not supported
H7: Habits positively affect the behavioral intention to adopt digital payments.	0.388***	Supported	0.365***	Supported
H9: Government incentives positively affect the behavioral intention to adopt digital payments.			0.036**	Supported
H10: Privacy concerns negatively affect the behavioral intention to adopt digital payments.			-0.031**	Supported
H11: Tax evasion aversion positively affects the behavioral intention to adopt digital payments.			0.128***	Supported
H8: Behavioral intention positively affects the use of digital payments	0.374***	Supported	0.373***	Supported

Source: authors' elaboration. *p < 0.05; **p < 0.01; ***p < 0.001; all other correlation are insignificant

R^2 was computed in order to assess the amount of variance in the endogenous constructs that is explained by the exogenous constructs (Hair *et al.*, 2022). Generally speaking, the higher R^2, the higher the in-sample predictive accuracy of the model. However, there is no general threshold for acceptable R^2 values, since it depends on the research disciplines as well as on the model complexity (Hair *et al.*, 2022). The average R^2 computed for the UTAUT2 model was quite high at 43.9 percent, while the average R^2 of the extended model was slightly higher at 44.5 percent. We then re-ran the tests for both models with significant paths only, i.e., excluding price value, to verify the change in the average R^2. We found that it decreased by only 0.06 percent and 0.02 percent, respectively.

The quality of the structural model was assessed by looking at the redundancy index. Redundancy shows "the amount of variance in the indicators measuring the variable that is explained by the exogenous latent variables that predict the endogenous variable" (Venturini and Mehmetoglu, 2019). Generally speaking, the higher the redundancy, the higher the predictive power of the latent independent variable, since no cut-off threshold has been suggested for redundancy so far (Hamdollah and Purya, 2016). The average redundancy of the UTAUT2 specification was equal to 0.542, whereas the average redundancy of the extended specification was slightly higher at 0.551.

7. Discussion

7.1 Theoretical contributions

This study adds value to the existing theory on the adoption of digital payments by extending the framework to prepaid, credit, and debit cards, instead of considering mobile payments alone. As pointed out in Section 2.2, the literature is mainly focused on mobile payment adoption by consumers. However, mobile payment is only a part of digital payments, which comprehend card payments as well. These methods are still far from being widespread, despite the benefits provided. Thus, our work contributes to the literature by providing evidence on the drivers to the adoption of digital payments in general in Italy.

We also contribute to the existing literature by further testing the explanatory power of UTAUT2. Our findings confirm the main structure of UTAUT2, with the only exception of price value, which is found to have no explanatory power on behavioral intention when applied to the digital payment technology, in contrast with the extant research conducted in other domains. A possible explanation for this result is that digital payments providers do not charge consumers for every transaction but apply monthly fees for payments cards. In some cases, there are no fees at all for payment cards, while mobile payment methods are usually free of charge for consumers. For these reasons, it might be difficult for a consumer to evaluate a tradeoff between the perceived benefits of a technology and the monetary cost for using it. Our finding suggests that when the technology under investigation is free of charge for the consumer

or costs are not charged according to use, price value might not play a significant role.

Our major theoretical contribution is integrating UTAUT2 with two variables that act at the meso-level, namely government incentives and tax evasion aversion; and a third constructs that is relevant when investigating a technology that can potentially map users' behavior, i.e., privacy concerns.

First, our analysis shows that privacy concerns have a negative impact on the behavioral intention to adopt digital payments. As explained in Section 2.1, since 2012, when UTAUT2 was first developed, the diffusion of new digital technologies has dramatically increased (OECD, 2020). As a consequence, the amount of personal data generated and shared has increased substantially, bringing more and more attention to the safeguard of one's privacy (OECD, 2017; Soodan and Rana, 2020). This is confirmed by our findings. For these reasons, we recommend future researchers that wish to investigate the adoption of a given technology to integrate the role of privacy concerns into their theoretical frameworks.

Second, our study shows that the aversion towards tax evasion has a positive, and one of the highest, impact on the behavioral intention to adopt digital payments. Unlike cash, digital payments are traceable, which means that they make it harder for a malevolent seller to conceal the transactions history and thereby hinder tax evasion attempts (Immordino and Russo, 2018). A consumer who is highly concerned with the negative externalities brought about by tax evasion is more likely to adopt digital payments, in order to prevent the seller from evading taxes. Tax evasion is a behavior that produces negative externalities that are specific to digital payment technology and therefore cannot be extended to the theory of adoption of technologies in general. However, each technology is adopted in a given context, with its own characteristics that might differ from one another. Therefore, we suggest that technology adoption theories should be adapted to the context in which the technology they investigate is used. A possible way to do so would be to integrate the specific factors producing positive or negative externalities that can be strengthened or weakened by that technology, as it is the case for tax evasion and digital payments.

The context, i.e., the meso-level, is also important with respect to external influence. For instance, in 2019 the Italian government introduced the Piano Italia Cashless which, as shown by our analysis, had a positive impact on the behavioral intention to adopt digital payments. This factor is of course specific to our study; however, it shows that if there are external factors that can affect the behavior of consumers, such as policies, they should be considered, while the relative theoretical framework should be adjusted accordingly.

Finally, to our knowledge, this study is unique as it examines the adoption of digital payments during the introduction of the Piano Italia Cashless in Italy, thereby allowing to investigate the impact of government support on the adoption of a given technology. By doing so, we also answer (Sivathanu, 2019) call for further investigation of the role of government support in the adoption of digital payment by consumers. The role of government incentives could be tested further, to contribute to the generalizability of our finding.

7.2 Practical implications

On the basis of the empirical research described above, it is found that the constructs performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, habits, government incentives, privacy concerns, and tax evasion aversion have a significant positive influence on the behavioral intention to adopt digital payments, which in turn positively affect the actual use of the technology.

Habits is the construct with the largest impact on the behavioral intention to adopt digital payments in Italy. This suggests digital payment providers to leverage the importance of a person's habits. For instance, they could provide benefits for frequent or loyal users.

Another important factor is performance expectancy. Its positive effect suggests that digital payment providers, as well as public authorities, should enhance the benefits that digital payments provide in the daily life to increase users' awareness. For instance, digital payment providers could run surveys among users to identify which features they value the most and they would like to have and try adding them to their product. Also, they could provide guidelines that highlight already existing or new features. Conversely, public authorities could develop communication campaigns describing tasks enabled by digital payments.

The third most-important construct is tax evasion aversion. Consequently, public authorities are encouraged to develop an institutional communication program about the negative externalities of tax evasion. The objective of such a program should be to increase consumers' awareness about the negative effects of tax evasion and, therefore, the importance to fight it.

Going to the other constructs, the positive impact of effort expectancy may encourage digital payment providers to work constantly to simplify the user's experience of the payment process, to reduce the effort required to the consumer, thereby increasing the behavioral intention to use such instruments. A proper user experience that makes digital payments pleasurable to use may also booster hedonic motivation, thereby increasing the behavioral intention to adopt digital payments. The influence of other people (social influence) is found to be significant as well. Consequently, digital payment providers are encouraged to foster higher social interaction in the use of digital payment instrument, for instance by offering zero-fee peer-to-peer transactions. Encouraging world of mouth can also persuade consumers to adopt digital payments, for example by introducing rewards to extant users who bring in new customers. Improving customer care, thereby enhancing the facilitating conditions, could also help in fostering the behavioral intention to adopt digital payments.

Public institutions can play a pivotal role in promoting the adoption of digital payments as well. The model has proved that the incentives designed by the Italian government had a positive impact on the behavioral intention to adopt the technology, which may encourage the Italian government itself to maintain such incentives in place and other governments to introduce similar policies.

Finally, privacy concerns is the only variable that has a negative impact, even though quite low. Public institutions are also encouraged to introduce, or to keep enforcing, laws that safeguard consumers' privacy when using digital payment instruments. When these laws already exist, the suggestion for public institutions is to develop communication campaigns with the goal of informing citizens on how to better protect their privacy when using digital payments.

8. Limitations and future research

The main limitation of this study concerns data gathering. The survey was conducted using the CAWI methodology, therefore targeting consumers that are already familiar with digital instruments, such as personal computers. Researchers are encouraged to integrate the CAWI methodology with other technology-free methods, e.g., CATI or CAPI.

Finally, future studies may address the impact of government incentives as well, in order to improve the generalizability. Also, we encourage researchers to further develop UTAUT2, adding variables that investigates also meso- and macro-level factors.

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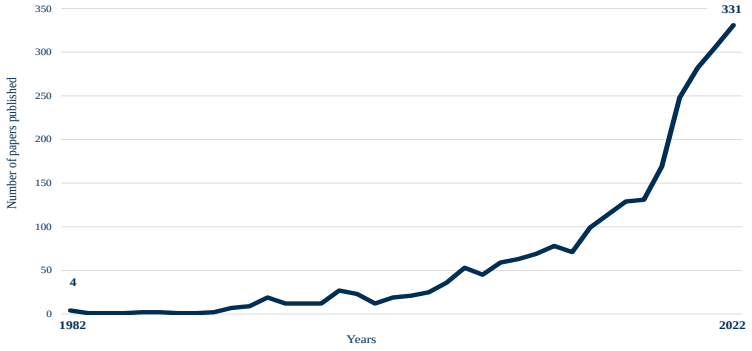
italian journal of management
Vol. 42, Issue 1, 2024

Appendix A

Fig. A1: Number of academic papers analyzing the topic of digital payments published in scientific journals indexed in Scopus



Source: authors' elaboration using Scopus data.
The following query was run on Scopus on January 28th, 2023: TITLE-ABS-KEY ((digital OR electronic OR card OR mobile OR smartphone) W/1 payment*)). Results were then limited to articles written in English and published in peer-reviewed journals before the end of 2022.

Appendix B

Tab. B1: Measurement scales for the constructs in the proposed research model

Construct	Item		Reference
Performance expectancy (PE)	PE_1	Digital payments help me pay more quickly.	Venkatesh et al. (2012)
	PE_2	Digital payments are more convenient than cash.	
	PE_3	Digital payments are useful in my daily life.	
Effort expectancy (EE)	EE_1	Digital payments are clear and understandable.	Venkatesh et al. (2012)
	EE_2	Learning how to use digital payments is easy for me.	
	EE_3	I find digital payments easy to use.	
Social influence (SI)	SI_1	People who are important to me use digital payments.	Venkatesh et al. (2012)
	SI_2	People who are important to me would like me to use digital payments.	
	SI_3	People who are important to me think that I should use digital payments	
Facilitating conditions (FC)	FC_1	I have the knowledge necessary to use digital payments.	Venkatesh et al. (2012)
	FC_2	I have the resources necessary to use digital payments.	
Hedonic motivation (HM)	HM_1	Using digital payments is satisfying.	Venkatesh et al. (2012)
	HM_2	Using digital payments is fun.	
	HM_3	Using digital payments is enjoyable.	
Price value PV)	PV_1	At the current price, digital payments provide a good value.	Venkatesh et al. (2012)
	PV_2	Digital payments are a good value for the money.	
	PV_3	Digital payments are reasonably priced.	
Habits (HA)	HA_1	I wish I could always pay with digital payments.	Venkatesh et al. (2012)
	HA_2	Using digital payments is natural to me.	
	HA_3	Using digital payment has become a habit for me	
Privacy concerns (PC)	PC_1	When using digital payments, I am concerned that the data can be stolen.	Dinev and Hart (2005)
	PC_2	I am concerned that the information I submit while using digital payments could be misused.	
	PC_3	Digital payments are a threat to my privacy.	
Tax evasion aversion (TEA)	TEA_1	Tax evasion causes negative consequences for the Italian economy.	Authors' own elaboration.
	TEA_2	Fighting tax evasion should be a priority in Italy.	
	TEA_3	Tax evasion is an urgent issue for Italy.	
Behavioral intention (BI)	BI_1	I intend to use cash less frequently in the future [a].	Venkatesh et al. (2012)
	BI_2	I will continue using digital payments in the future.	
	BI_3	I intend to continue using digital payments in the future.	

Source: authors' elaboration. [a] Reversed scale.

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italian journal of management

ISSN 0393-5108
ISSN 2785-549X
DOI 10.7433/s123.2024.09
pp. 217-240

Blockchain technology adoption in food label systems. The impact on consumer purchase intentions

Received
13th November 2023
Revised
22nd December 2023
Accepted
12th February 2024

Fabiana Sepe

Abstract

Framing of the research. *Food labels have a significant impact on shaping consumers' intentions to purchase food products. The adoption of blockchain technology with regard to food labels holds potential as an effective means of enhancing the data accessible to consumers, thereby shaping their purchasing patterns.*

Purpose of the paper. *This study adopts the Unified Theory of Acceptance and Use of Technology as a theoretical framework to understand how blockchain technology adoption in food label systems might influence consumers' intention toward purchasing labeled food.*

Methodology*. A research model with six hypotheses has been developed and tested on a sample of 825 users. The proposed model also highlights the importance of perceived trust and perceived product transparency on customers' purchase intentions. Data have been analyzed via a PLS-SEM approach.*

Findings*. Results show that the adoption of blockchain technology to protect information throughout the food supply chain can positively influence consumers' purchase intentions.*

Research limits. *This work has some limitations, which could serve as a pathway for future investigations. First, it has been conducted within a single country (Italy). Next, though it meets the required sample size for conducting analysis, future studies could enhance the number of observations to reinforce this study's findings.*

Practical implications. *This research contributes to a deeper understanding of the role of blockchain technology in the food industry by providing empirical evidence of its potential as a valuable tool for sustaining company purchases.*

Originality of the paper. *This study advances scientific knowledge of blockchain technology in the specific context of the food sector.*

Key words: *blockchain technology; food label; behavioral intention*

1. Introduction

In 2022, the worldwide food industry realized a total revenue of US$8,670 billion (Statista, 2023). The food market's global revenue is predicted to see steady growth from 2023 to 2028, with a total increase of 3.6 trillion U.S. dollars, representing a growth rate of 38.46%. This continuous growth is expected to culminate in 2028 when revenue is estimated to reach a new record high of 12.97 trillion U.S. dollars. It is worth noting that the food market has experienced a consistent upward trend in revenue over the past several years (Statista, 2023).

Currently, the industry is grappling with significant pressures and hurdles, including the pervasive influence of e-commerce, the implementation of cutting-edge digital technologies, and the growing attention paid to sustainability practices (Harvard Business Review, 2023). Accordingly, as reported by IBM (2022), more than half of consumers express their willingness to pay a premium for sustainably sourced products. The intertwining of digitalization and sustainability within the food industry heralds a transformative era in which technological advancements are harnessed to amplify sustainable practices (Jansen, 2003; Parmentola *et al.*, 2022). The introduction of digital technologies, such as blockchain technology (BCT), allows businesses to gather and analyze data to promote sustainability in areas that were once a black box (Oguntegbe *et al.*, 2021). Specifically, by harnessing the power of digitalization, the food industry is poised to usher in a new paradigm of responsible and sustainable production, transparent sourcing, and reduced environmental impact. Because customers are becoming more aware of the quality and safety of products in the food sector (World Health Organization, 2019), both academics and practitioners are paying more attention to BCT as a tool for food traceability, safety, and transparency (Feng *et al.*, 2020; Lin *et al.*, 2021). The adoption of BCT extends benefits not solely to customers seeking more comprehensive information about food products but also to companies (Stranieri *et al.*, 2021). Information asymmetry diminishes when customers have insight into the provenance and transit of their purchases, thereby contributing to the mitigation of health hazards (Yoo *et al.*, 2015). This augmented transparency equips consumers with improved capabilities to evaluate the attributes of a specific product, which instills trust and fosters more informed choices (Ghahremani-Nahr *et al.*, 2022). Specifically, recent trends indicate an increased awareness of the source and authenticity of food products. These factors are being noted as pivotal aspects of evaluating and making decisions that influence consumer preferences (Marozzo *et al.*, 2022).

Previous research has provided a preliminary understanding regarding the regulatory aspects of BCT implementation in the food industry (Li *et al.*, 2023; Duan *et al.*, 2020). These studies focused primarily on investigating the potential benefits associated with adopting BCT, such as improving traceability efficiency (Feng *et al.*, 2020) and supply chain transparency (Sunny *et al.*, 2020). However, there are also challenges, including scalability, lack of legislation, and immature technology (Zhao *et al.*, 2019; Lohmer and Lasch, 2020). Moreover, prior research (Rogerson and Parry, 2020) has demonstrated that BCT features play a significant role in establishing information transparency throughout the supply chain, involving different participants. Tokkozhina *et al.* (2023) investigated the implications of information accessibility in the context of adopting BCT pilots within the supply chain. Their findings revealed that BCT's reputation as a trust-building technology does not eliminate the need for trustworthy relationships before adoption due to the human intervention required for information input.

On the other hand, Treiblmaier and Petrozhitskaya (2023), focusing on the consumer side, have studied how BCT-based loyalty programs

transform B2C relationships via innovative customer services that maintain important properties of a sharing economy. Nevertheless, only limited research has investigated how the use of BCT to trace food products impacts consumers' perception of product quality as a mediating variable and, consequently, their purchase intention (Treiblmaier and Garaus, 2023). Thus, studies delving into the effective communication of food product attributes to end consumers and the potential impact of BCT on food label systems are currently scarce, though they are gaining notable traction in recent scientific research. As consumers become increasingly conscious of their food choices, there is a growing need to both explore users' intention toward adopting BCT to purchase food products and understand how consumers' perceived transparency of food product information is an important intrinsic mechanism by which BCT experiences affect consumer perceived trust (Liu *et al.*, 2023).

To address this research gap, this paper aims to develop an understanding of how BCT adoption in food label systems might influence consumers' intention toward purchasing labeled food, emphasizing the role of both perceived product transparency and perceived trust. Furthermore, it assesses whether distinct behavioral patterns exist based on demographic characteristics, specifically comparing the intentions of younger generations (Generation Z and Millennials) to those of older generations (Generation X and Boomers) regarding the use of BCT-based food labels.

In line with the research objective, the following research question has been posed:

RQ: How and to what extent can the use of blockchain technology impact consumers' perceptions of food products and their purchase intentions?

To answer this research question and achieve the research aim, this study applies the Unified Theory of Acceptance and Use of Technology (UTAUT) and tests a model that incorporates both perceived trust and perceived product transparency.

This paper is structured as follows: Section 2 is based on the relevant literature, starting with the UTAUT, which provides the theoretical foundation for our study, and then elaborates on blockchain-based traceability systems in the food industry. Section 3 regards the conceptual model and the hypotheses development. Section 4 focuses on the research methodology, then discusses the findings and their implications for both scholars and practitioners. Finally, the concluding remarks, with limitations and future research hints, are provided.

2. Theoretical foundation

2.1 Unified Theory of Acceptance and use of Technology

The UTAUT model, introduced by Venkatesh *et al.* (2003), explains and predicts consumer behavior; therefore, it is one of the most up-to-date

models for studying technology acceptance (Mukherjee *et al.*, 2023). In the UTAUT, four preceding factors - performance and effort expectancies, social influence, and facilitating conditions - determine the behavior (use) intention of information technology. The four determinants are the core factors that affect intention and behavior, whereas facilitating conditions directly affect behavior. This study uses the UTAUT to measure users' intention toward adopting BCT to purchase food products.

Among all technology acceptance models, such as the Technology Acceptance Model (TAM - Davis, 1989), the Theory of Reasoned Action (TRA - Fishbein and Ajzen, 1975), and the Theory of Planned Behavior (TPB - Ajzen, 1991), the UTAUT model has been proven to be the superior and most widely used one due to its simplicity, robustness, and parsimony (Tarhini *et al.*, 2016).

The UTAUT has been implemented in past research for the adoption of blockchain in the supply chain (Wong *et al.*, 2020; Francisco and Swanson, 2018), blockchain in the operation and supply chain (Queiroz *et al.*, 2021), blockchain in the retail supply chain (Mukherjee *et al.*, 2023), blockchain in the agri-food supply chain (Sharma *et al.*, 2023a), blockchain in the banking sector (Jena, 2022), and blockchain in the tourism domain (Chang *et al.*, 2022).

2.2 Blockchain-based traceability systems: A focus on perceived trust and product transparency

The food supply chain operates as a complex system, involving a plethora of stakeholders and multiple intermediary processes (Vu *et al.*, 2023). This complexity might lead to information imbalances and potential data loss during transitions. In such a context, BCT, known for its robust and decentralized nature, offers a solution to address issues of food fraud and security (Singh and Sharma, 2023). BCT works as a digital transaction ledger that operates across a computer network without relying on a trusted third party (Treiblmaier, 2018). It consists of unchangeable data blocks, each containing a list of transactions and a unique reference to preceding blocks. The term "blockchain" is sometimes used interchangeably with "distributed ledger," which is a specialized type of distributed database (Rana *et al.*, 2021). This technology assigns distinct digital identifiers to food products, facilitating traceability throughout the supply chain, including information such as batch numbers and expiration dates.

The implementation of a blockchain-based food ledger and transaction registry makes it possible to prevent fraud and establish a means of identifying instances of foodborne illnesses. This approach represents a significant advancement in promoting the sharing of on-farm data (Bumblauskas *et al.*, 2020). Specifically, both data immutability and the distribution among different nodes, each of which shares an identical copy of all recorded transactions, ensures a level of traceability that was not possible before BCT emergence (Treiblmaier, 2019). In this light, Centobelli *et al.* (2021) figured out that the two factors of trust and transparency determine blockchain platform adoption in a supply chain context. Accordingly, Dubey *et al.* (2020) confirmed that using BCT can

improve the traceability and transparency of supply chains and enhance the amount of swift trust occurring in temporary organizational structures (Treiblmaier and Garaus, 2023). Therefore, researchers suggest adopting BCT for products for which there is high consciousness of traceability (such as those related to safety and quality concerns, e.g., food products) (Yiannas, 2018; Behnke and Janssen, 2020). Information about a product's attributes, such as its authenticity, integrity, and origin, assures customers of their purchasing decisions (Mingione *et al.*, 2020). In this optic, BCT can allow for the establishment of each of these by enabling trackability, traceability, certifiability, and verifiability (Montecchi *et al.*, 2019). This is because BCT adds a layer of credibility, as its decentralized nature ensures that no entity can delete a previously stored piece of information (Min, 2019).

3. Conceptual framework and hypothesis development

Given the lack of empirical evidence of the adoption of BCT and issues related to trust and perceived product transparency within the food label system, this work seeks to fill this gap by extending the original UTAUT model (Venkatesh *et al.*, 2003) with perceived trust (Yeh *et al.*, 2019) and perceived product transparency (Zhou *et al.*, 2018), as shown in Figure 1.

3.1 UTAUT-related constructs

Performance expectancy (PE) defines the degree to which the use of a new technology can provide individuals with the expected advantages in performing specific activities (Venkatesh *et al.*, 2003). In the context of BCT adoption, up-to-date literature has proved that PE positively influences individuals' intentions (Sharma *et al.*, 2023a). Thus, the following hypothesis has been derived:

H1: Performance expectancy has a positive influence on behavioral intention to purchase blockchain-based labeled food products.

Effort expectancy (EE) is the measure of ease associated with using a system (Venkatesh *et al.*, 2003). In this study, EE indicates the ease of adopting BCT in food labeling. PE and EE are related to each other, as they are aligned toward the system's efficiency, expectations, and effectiveness (Francisco and Swanson, 2018).

Thus, the following hypothesis has been formulated:

H2: Effort expectancy has a positive influence on behavioral intention to purchase blockchain-based labeled food products.

Social influence (SI) refers to the degree to which a person perceives the importance that other individuals assign to using the new system (Venkatesh *et al.*, 2003). Thus, SI regards how people influence the behavior of others in adopting BCT. Sharma *et al.* (2023a) found that SI is highly

affected by society's, family members', and friends' beliefs and actions. The following hypothesis captures this relationship:

H3: Social influence has a positive influence on behavioral intention to purchase blockchain-based labeled food products.

Facilitating conditions (FC) indicate the degree to which an individual believes that the organizational and technical infrastructure exists to support the system's use (Venkatesh *et al.*, 2003). In this work, FC concerns the availability of necessary resources to the consumers with regard to using blockchain labels while purchasing food. In addition, in line with Sharma *et al.* (2023a), if there is sufficient technological and human support for BCT, consumers will be more likely to engage with this technology and have a more pleasant experience with it. Based on these arguments, the following hypothesis has been formulated:

H4: Facilitating conditions have a positive influence on behavioral intention to purchase blockchain-based labeled food products.

3.2 Newly added constructs to UTAUT

As stressed in past research, consumer trust forms the basis of product acceptance and long-term relationships with brands (Wu *et al.*, 2021; Siegrist and Hartmann, 2020). An important factor in building trust among consumers is perceived product transparency (PPT - Zhou *et al.*, 2018), especially in the context of food labeling systems (David *et al.*, 2022).

PPT refers to the extent to which consumers can access and understand information about a product and its origin, ingredients, and production processes (Zhou *et al.*, 2018). In this light, as mentioned above, BCT in food label systems provides transparency and traceability in the whole food supply chain, which, in turn, can help consumers make informed choices about the products they purchase, allowing them to trace the journey of a food product from farm to fork (Mollenkopf *et al.*, 2022).

PPT, therefore, represents consumers' perception of the degree to which this information is accessible and trustworthy (Sander *et al.*, 2018). Accordingly, when consumers believe that they have access to reliable and comprehensive information about a product, they are more likely to trust BCT-enabled food label systems (Liu *et al.*, 2023). This leads to the following hypothesis:

H5a: Perceived product transparency has a positive influence on perceived trust.

Prior research (Berry *et al.*, 2015) confirms that consumers often use product labeling as a basis for their purchasing decisions. Likewise, Lee *et al.* (2020) demonstrated that traceable and transparent labels, such as blockchain-based food labels, can increase consumers' purchase intentions. In this regard, the behavioral intention to purchase labeled food products in a blockchain context indicates consumers' willingness to choose and buy

products with blockchain-verified labels. Thus, the following hypothesis has been derived:

H5b: Perceived product transparency is positively associated with behavioral intention to purchase blockchain-based labeled food products.

Perceived trust (TR) is a complex psychological construct influenced by various factors, including reliability, credibility, and transparency (Shankar *et al.*, 2002). In a blockchain domain, TR refers to consumers' confidence in the accuracy and integrity of the information recorded on the blockchain (Yeh *et al.*, 2019). BCT's inherent characteristics, such as decentralization and immutability, contribute to the perception of trustworthiness (Singh and Sharma, 2023). Consumers who trust a blockchain-based food label system are more likely to perceive that the information provided about a product is accurate and that the product meets the specified quality and safety standards. TR in such a system can lead to increased intention to buy blockchain-based labeled food products. Hence, the following hypothesis has been formulated:

H6: Trust positively influences behavioral intention to purchase blockchain-based labeled food products.

3.3 The moderating effect of age

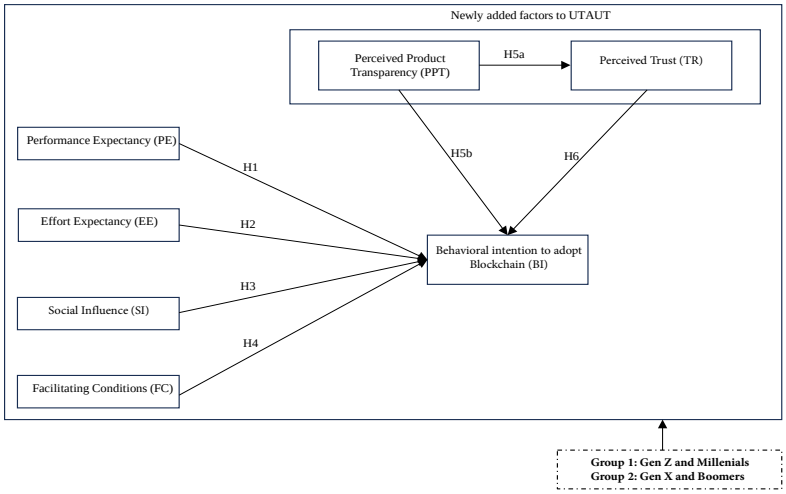
Demographic differences among individuals are associated with their different behavioral intentions (Zhao *et al.*, 2018) to purchase blockchain-based labeled food products.

Specifically, the two younger generations (Millennials, born from 1981 to 1996, and Gen Z, born from 1997 to 2012), both known as digital nomads, share many generational characteristics that are different from those of their counterparts (Garikapati *et al.*, 2016; LaTour *et al.*, 2020; Fan *et al.*, 2023). They are generally considered more tech-savvy and tech-connected than the older generations, such as Boomers (born from 1946 to 1964) and Generation X (born from 1965 to 1976). Additionally, Millennials and Gen Z consumers follow healthy eating habits, and their decisions are linked with sustainable activism (Su *et al.*, 2019). This is in line with the EIT Food research (2021), according to which Millennials and Gen Z people are constantly searching for a healthy food system in which they can actively participate.

Consistent with the theoretical frame of this paper, the following hypothesis has been derived:

H7: Age moderates the effect among UTAUT-related constructs and newly added constructs on behavioral intention to purchase blockchain-based labeled food products.

Fig. 1: The proposed research model



Source: our elaboration

4. Methodology and research design

Measurement items and latent constructs, including PE, EE, SI, FC, and BI, were based on the established scales in order to justify validity (Venkatesh *et al.*, 2003). Likewise, newly added constructs were drawn from previous studies on perceived trust (Yeh *et al.*, 2019) and perceived product transparency (Zhou *et al.*, 2018). All constructs were reflectively measured using multiple-item scales already established in the relevant literature and were slightly adapted to the research context when necessary (Becker *et al.*, 2023).

This study used a hypothetical scenario (or vignettes, as they are sometimes called)[1] (Weber, 1992; Siponen and Vance, 2010), as this enables the examination of consumer decision-making behavior in emerging technology contexts (Della Corte *et al.*, 2023). Specifically, to gather insights into respondents' awareness of and opinions on the use of BCT in the food labeling system, before proceeding with the survey, an image of a QR code on a food product was incorporated into the first part of the questionnaire, along with a brief description of what BCT is and how it functions within the food industry.

After that, the questionnaire constituted two sections: Section A encompassed demographic information, while section B included seven constructs and 25 associated items (see appendix A). A 7-point Likert scale, ranging from strongly disagree (1) to strongly agree (7), was applied to measure the items of each construct.

[1] "Scenarios are defined as descriptions of a person or a social situation which contain precise reference to what are thought to be the most important factors in the decision-making or judgement-processes of respondents" (Weber, 1992, p. 137).

While previous studies had validated most of the items, the adapted measurement items, along with new items, were subject to content validity and reliability in the context of BCT. To ensure content validity, the items and constructs were discussed with three academics who maintained extensive practical and theoretical knowledge about BCT. Following their feedback, an improvement was made: The wording and sequence of the items associated with the perceived product transparency and perceived trust were changed to make them clearer in the context of BCT. The instrument was then pilot-tested with 32 participants. The reliability of measurement items and associated constructs was evaluated such that the Cronbach's alpha value for each construct was higher than the 0.7 threshold (Hair, 2009). The pre-test participants were excluded from the main survey.

The final survey was administered using the LimeSurvey platform from February to May 2023. It gathered 897 answers from university students (enrolled in bachelor's, master's, and PhD courses at the University of Naples Federico II and the University of Suor Orsola Benincasa, Italy) and their relatives. As mentioned above, the rationale for surveying students (Millennials or Gen Z) stemmed from their higher comfort level in utilizing smartphones, a crucial factor for reading QR codes, even during in-store purchases (Ho *et al.*, 2022; Priporas *et al.*, 2017). Additionally, previous studies have frequently employed student samples to gain insights into how younger generations navigate new technologies (Gardner and Davis, 2013; Cavaliere and Ventura, 2018) and make food choices (Steenis *et al.*, 2017; Madilo *et al.*, 2020). At the same time, we gathered responses from Gen X and Boomers to test their propensity for using cutting-edge technology to obtain information about food labels.

After filtering (checking for completeness and correctness), 825 responses were included in the final dataset. Specifically, 559 respondents were in the age group between 18 and 42 years (Gen Z and Millennials), while 226 respondents were in the age group between 43 and 70 years (Gen X and Boomers). The bulk of respondents (68%) attended university courses. In detail, 315 out of 559 students were attending BA courses in Agricultural Science and Marketing & Management, 228 students were enrolled in the MSc programs in Corporate Strategy & Communication and Innovation Management, and 16 were attending PhD courses in Management. Furthermore, the sample maintained the following split: 62% female and 38% male.

5. Results

In this research, behavioral intention (BI) and perceived trust (TR) are the dependent variable. The drivers that affect them are unobservable variables called latent variables (LVs), each measured by several observed indicators usually defined as manifest variables (MVs). Therefore, structural equation modeling (SEM) was considered to be the most suitable statistical methodology for carrying out the analysis.

Data were studied using a PLS-SEM approach, with SmartPLS version 4 (Wong, 2013). This allowed us to focus on predicting the dependent variables and did not require normally distributed data (the Kolmogorov-

Smirnov test showed that no item was normally distributed (P values < 0.001)). Moreover, PLS was recently used in several studies on BCT usage in different contexts (e.g., food supply chain - Khan *et al.*, 2022 and Dehghani *et al.*, 2022; operations and supply chain management - Queiroz *et al.*, 2021; tourism industry - Chang *et al.*, 2022).

Based on Hair *et al.* (2017), a two-stage analytical approach (measurement model and structural model) was applied.

PLS-SEM was implemented, drawing on established procedures and following all recent recommendations (Starsted *et al.*, 2023; Cheah *et al.*, 2023). In particular, the application of CVPAT, which was performed using 10 folds and 10 repetitions as settings, was of the fundamental importance for the assessment of the predict power of UTAUT (Sharma *et al.*, 2023b).

At least, the multigroup analysis (MGA) with age as moderator has been applied. Before performing MGA, the measurement invariance of the composite model routines has been performed (Cheah *et al.*, 2023).

5.1 Measurement model

As all constructs were specified as reflective, the study dealt with the measurement model assessment by examining the reliability (through the Cronbach's alpha scores and composite reliability (CR) of each construct) and validity (both the average variance extracted (AVE) scores and the factor loadings) (Fornell and Bookstein, 1982). As reported in Tab. 1, all loadings were higher than 0.60 (Henseler *et al.*, 2009), each construct's Cronbach's alpha and CR scores were higher than 0.70, and the average variance extracted (AVE) score of each construct was higher than 0.50 (Hair *et al.*, 2017).

Next, discriminant validity, which is one of the key building blocks of model evaluation (Hair *et al.*, 2010), was checked using two criteria: the Fornell-Larcker criterion and the Heterotrait-Monotrait criterion (Henseler *et al.*, 2015). As shown in Tab. 2, the square root of the AVE score for each construct was higher than its highest correlation with the other constructs, and the HTMT ratios were less than the 0.90 threshold. This way, both criteria provided empirical evidence for discriminant validity.

Also, the measurement invariance across the two groups of respondents had been assessed. Measurement invariance must be established before MGA is conducted, to exclude the fact that differences in the estimates are the results of the different content and meanings of the constructs across groups (Hair *et al.*, 2019). Thus, the measurement invariance of composite models (MICOM) routine was applied. Initially, the study ensured that the configuration remained consistent by maintaining uniformity in indicators, data treatment, and algorithm settings for both groups. Subsequently, the MICOM procedure progressed to examine compositional invariance, verifying that the correlations between the composite scores of the two groups remained close to 1. The permutation test (10,000 permutations; Tab. 3) indicated that the null hypothesis for all constructs could not be rejected, confirming compositional invariance (Henseler *et al.*, 2016). Consequently, partial measurement invariance was established, allowing for meaningful comparisons between multiple groups (Hair *et al.*, 2019).

Tab. 1: Validity and Reliability results

Constructs	Items	Outer Loading	Composite reliability (rho_a)	Composite reliability (rho_c)	Alpha	AVE
Performance expectancy (PE)	PE1	0.891	0.930	0.950	0.929	0.825
	PE2	0.923				
	PE3	0.923				
	PE4	0.896				
Effort Expectancy (EE)	EE1	0.898	0.897	0.926	0.892	0.758
	EE2	0.919				
	EE3	0.857				
	EE4	0.802				
Social Influence (SI)	SI1	0.868	0.744	0.841	0.709	0.643
	SI2	0.617				
	SI3	0.892				
Facilitating Conditions (FC)	FC1	0.855	0.848	0.895	0.843	0.681
	FC2	0.862				
	FC3	0.820				
	FC4	0.759				
Perceived Trust (TR)	TR1	0.902	0.841	0.897	0.826	0.746
	TR2	0.923				
	TR3	0.757				
Perceived Product Transparency (PPT)	PPT1	0.923	0.963	0.971	0.963	0.871
	PPT2	0.943				
	PPT3	0.941				
	PPT4	0.954				
	PPT5	0.906				
Behavioral Intention (BI)	BI1	0.964	0.961	0.974	0.961	0.927
	BI2	0.962				
	BI3	0.962				

[a] All constructs are reflective; all items were rated on a 7-point Likert scale, with the extremes being 1 = completely disagree and 7 = completely agree

Source: our elaboration

Tab. 2: Discriminant validity

	BI	EE	FC	PE	PPT	SI	TR
BI	**0.963**	0.872	0.738	0.828	0.744	0.409	0.820
EE	0.807	**0.870**	0.817	0.896	0.851	0.370	0.890
FC	0.669	0.710	**0.825**	0.702	0.794	0.306	0.818
PE	0.782	0.815	0.627	**0.908**	0.761	0.326	0.827
PPT	0.745	0.790	0.718	0.721	**0.934**	0.331	0.895
SI	0.337	0.292	0.231	0.264	0.266	**0.802**	0.367
TR	0.729	0.765	0.684	0.728	0.800	0.268	**0.864**

Note: Fornell-Larcker criterion values are shown below the diagonal, whereas HTMT values are show above the diagonal

Source: our elaboration

Tab. 3: Compositional invariance: results of the permutation test

Latent variable	Original correlation	Correlation permutation mean	5.0% quartile	Permutation p-value
BI	1.000	1.000	1.000	0.968
EE	1.000	1.000	1.000	0.697
FC	1.000	0.999	0.998	0.928
PE	1.000	1.000	1.000	0.586
PPT	1.000	1.000	1.000	0.952
SI	1.000	0.995	0.980	0.997
TR	1.000	1.000	0.999	0.547

Source: our elaboration

5.2 Structural model analysis

The results for the structural model assessment are illustrated in Tab. 4. To test the proposed hypotheses, the path coefficients have been calculated using a bootstrapping procedure (10000 resamples) (Kock, 2018). All hypotheses have been confirmed. The model has been tested for the common method bias (CMB) with the full-collinearity approach. In the analysis, the VIFs were always far below the problematic value of 5, meaning the absence of multicollinearity (Hair *et al.*, 2016; Starstedt *et al.*, 2023). Furthermore, as reported in Tab. 5, R^2 values are above the .10 cut off (Falk and Miller, 1992), suggesting that the model predictive power is good as it explains about 73% of the BI variance and 64% of TR variance. Moreover, Q^2 values support the predictive relevance. Indeed, we obtained a Q^2 higher than 0 (Shmueli *et al.*, 2019).

Tab. 4: Results of structural model assessment and hypotheses testing

HP	Relations	Path coefficients	P values	VIF	Support
H1	PE -> BI	0.292	0.000	3.261	Yes
H2	EE -> BI	0.304	0.000	4.389	Yes
H3	SI -> BI	0.091	0.000	1.101	Yes
H4	FC -> BI	0.094	0.026	2.389	Yes
H5a	PPT -> TR	0.800	0.000	1.000	Yes
H5b	PPT -> BI	0.128	0.012	3.807	Yes
H6	TR -> BI	0.092	0.023	3.428	Yes

Source: our elaboration

Tab. 5: R-square values

	R-Square	Q-square
BI	0.730	0.721
TR	0.641	0.640

Source: our elaboration

Finally, the predict power of the model was assessed using the $PLS_{predict}$ algorithm with 10 folds and 10 repetitions (Shmueli *et al.*, 2019). Specifically, the CVPAT has been applied to evaluate the predictive accuracy

of the model against a naïve indicator-averages prediction benchmark and conservative linear model prediction benchmark. The results for the overall model (tab. 6) showed that the model had stronger predictive validity for behavioral intention rather than for trust.

Tab. 6: CVPAT results

Benchmark	Level of analysis: overall model		
		Average loss difference	P value
$CVPAT_{benchmark\_IA\ construct}$	Behavioral intention	-2.183	0.000
$CVPAT_{benchmark\_IA\ construct}$	Trust	-1.419	0.000
$CVPAT_{benchmark\_IA\ overall}$	Overall model	-1.801	0.000
$CVPAT_{benchmark\_LM\ construct}$	Behavioral intention	-0.014	0.463
$CVPAT_{benchmark\_LM\ construct}$	Trust	0.132	0.000
$CVPAT_{benchmark\_LM\ construct}$	Overall model	0.059	0.004

Note: IA = naïve indicator-average prediction benchmark; LM = conservative linear model prediction benchmark

Source: our elaboration

5.3 Multi-group analysis

To examine the moderating effect of age, this study performed a multi-group analysis. A multi-group analysis is often used to compare multiple samples across multiple groups for any identified SEM and to test for significant differences across multiple groups (Papastathopoulos *et al.*, 2020). Before the multi-group analysis, the respondents were divided into two groups based on their age, namely, young people (Generation Z and Millennials, n = 559) and old people (n = 266). Based on tab. 7, all relationships were not supported apart from H6. Thus, the path from TR to BI was moderated by age, while the other relationships were not moderated. Specifically, TR had a statistically significant effect on BI in the young group (standardized estimate = 0.051**) but not in the old group (standardized estimate = -0.004).

Tab. 7: Multigroup analysis with age as moderator

H7		Standardized path coefficient			
Relationships	Young (N = 559)	Old (N = 266)	Difference (old - young)	P-value	Results
PE -> BI	0.292***	0.286***	-0.007	0.472	Not supported
EE -> BI	0.321***	0.260**	-0.061	0.296	Not supported
SI -> BI	0.099***	0.067	-0.034	0.249	Not supported
FC -> BI	0.076	0.148*	0.073	0.207	Not supported
PPT -> TR	0.812***	0.780***	-0.033	0.193	Not supported
PPT -> BI	0.078	0.215**	0.137	0.092	Not supported
TR -> BI	0.151**	-0.004	-0.156	0.034*	Supported

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

Source: our elaboration

6. Discussion

The results of this study contribute to the extant literature arguing that customers are willing to use BCT to purchase labeled food because they perceive BCT to be a dependable foundation ensuring controlled access to information and a reduction in safety and quality risks. Furthermore, BCT allows individuals interested in purchasing a food product to readily validate information, such as its origin and ingredients.

Specifically, all research hypotheses were confirmed, helping not only to augment the existing body of knowledge on the theme under investigation but also to address the RQ: *How and to what extent can the use of blockchain technology impact consumers' perceptions of food products and their purchase intentions?* To address this RQ, this work applied an extended UTAUT model incorporating two new constructs into the original model, namely, perceived product transparency and perceived trust. As for the UTAUT-based constructs (PE, EE, SI, FC), the research's findings confirm their positive impact on BI to purchase blockchain-based labeled food products. On the same page, the newly added factors to UTAUT also show a positive correlation with BI. Precisely, individuals perceive information released by BCT-enabled food labels as being more detailed, transparent, and reliable. This PPT, in turn, positively impacts TR because consumers are more likely to perceive food products as accurate and conform to the specified quality and safety standards. Therefore, both PPT and TR play a key role as antecedents of behavioral intention to adopt BCT when food products are purchased.

Furthermore, to test the moderating effect of age, this study performed a multi-group analysis. The results demonstrated that only TR has a significant effect on BI in the case of Gen Z and Millennials. In the realm of food labels, these tech-savvy generations perceive BCT as a reliable system for tracing the origins and journey of food products. Conversely, Gen X and Boomers, who might be less immersed in the digital landscape, could harbor reservations or be less accustomed to the intricacies of BCT. Thus, the cultural gap and varying levels of technological exposure contribute to a disparity in the trust placed in BCT-based food labels.

The results of this paper offer not only theoretical implications but also practical insights and solutions to the real-world issues that prompted the present research.

7. Theoretical and practical implications

This work contributes both theoretically and practically to current literature.

From a theoretical point of view, as highlighted in past research, blockchain-based food labeling is an important tool for food supply chain participants (Duan *et al.*, 2020). First, producers use it to communicate with consumers and promote their products (Stranieri *et al.*, 2021), while food regulators see it as a means of educating consumers or enforcing food quality standards (Kamble *et al.*, 2020). At the same time, as this

study's findings reveal, consumers perceive blockchain-based food labels as relevant sources of information on different product attributes, enabling them to make informed choices.

Moreover, the empirical study affirms the robustness of the extended UTAUT model, as it substantiates the fact that both perceived trust and perceived product transparency play significant roles in influencing the behavioral intention to purchase food label products utilizing BCT. The positive impact observed in the study underscores the importance of these factors in shaping consumer attitudes and behaviors. The validation of the extended UTAUT model provides empirical support for the notion that beyond technological factors, elements such as trust and transparency are crucial determinants in driving consumer acceptance and adoption of BCT-based food products. As both scholars and practitioners navigate the landscape of emerging technologies, acknowledging and incorporating these influential factors into marketing studies and strategies becomes imperative for successful implementation and widespread consumer adoption.

The results also reveal that younger generations trust BCT-based food labeling more than do older generations. In such a context, traversing the post-pandemic landscape underscores the influential role of Millennials and Gen Z in shaping the food industry's trajectory (Orea-Giner and Fusté-Forné, 2023). Their attention to bioactive ingredients, adherence to food safety measures, and preference for sustainable practices are critical determinants that significantly impact the evolution of the food sector (Su *et al.*, 2019). Thus, gaining valuable insights into emerging trends, innovative solutions, and potential shifts in consumer behavior is achievable through the careful monitoring of the beliefs and intentions of these younger generations (Yamane and Kaneko, 2021; Kiliç *et al.*, 2021). This approach contributes to a nuanced understanding of the evolving dynamics within the food industry, providing essential knowledge for informed decision-making and strategic planning. This is in line with Ji *et al.* (2022) I, according to whom supply chain members should focus on the types of consumers in the market to understand consumer psychology.

Additionally, the benefits related to the adoption of BCT recall what has been clearly indicated in a report published by the FAO (2017), according to which strengthening the linkages between farms, markets, and consumers can generate greater income growth and job creation. On the same page, to be profitable within a fiercely competitive landscape, retailers must foster close collaboration with their suppliers. This requires the sharing of comprehensive information about the source and logistics of their products. Hence, enhanced communication with their customers can be a strategic advantage for companies operating in the food industry, as it can boost their competitiveness. Conversely, a dearth of information exchange can have adverse effects, raising concerns among consumers regarding the quality of food products.

With the implementation of BCT, all information generated within supply chains becomes auditable in real-time, offering a means of assessing the credibility and accuracy of this data. This enhances traceability in terms of product transparency and significantly boosts a company's image and

reputation, leading to positive effects on customers' purchasing intentions. In these terms, the findings of this work offer another compelling rationale for managers to invest in BCT, as it facilitates communication between all supply chain participants. Specifically, due to the novelty of BCT, companies might experience a collective benefit as both startups and technology incumbents raise awareness of the use of BCT in the food industry. Stemming from another result of this study, consumers' high propensity and heightened awareness could lead to overall growth and opportunities for all parties.

8. Conclusion, limits and future research paths

BCT has rapidly evolved in different industries, including the food sector, to enhance the reliability, traceability, transparency, and trustworthiness of information within supply chains. Consumers in the food industry have become increasingly aware of these factors, thus influencing their purchasing decisions. Surprisingly, the impact of the adoption of BCT on consumer purchase intentions had not been thoroughly examined until now. In such a context, this study has provided preliminary insights into how the utilization of BCT to safeguard label information can positively influence consumer purchase intentions, which can serve as a reliable proxy for actual purchasing behavior.

The findings of this study contribute to a deeper understanding of BCT's role in the food sector, shedding light on its potential benefits on the consumer side. This knowledge, in turn, can be valuable for industry leaders and policymakers, offering evidence to support the broader adoption of BCT in the food industry.

While this study is not without its limitations, it also opens the door to potential directions for future studies. In fact, first, while this research met the required sample size for conducting analyses, there are several avenues for future research that could produce a better understanding of the topic under investigation. Specifically, future studies could increase the number of observations to reinforce the findings of this research. Additionally, researchers could incorporate additional control variables. For instance, the inclusion of institutional and cultural variables (e.g., institutional factors, cultural diversity) in future studies would allow for a more comprehensive examination of the complexities surrounding the decision to adopt BCT in the food industry. Furthermore, while this study focused on consumers' intentions to purchase, future research could directly measure real purchase actions. This would provide a more concrete understanding of how BCT adoption influences consumer buying decisions. Additionally, considering the high implementation costs associated with BCT, future studies could explore the point at which the benefits derived from increased purchase intentions and actual purchases outweigh the overall expenses incurred in implementing BCT solutions.

Moreover, while this study focused on the food sector as an appropriate context in which to study the advantages of BCT in terms of enhancing information trustworthiness and reliability, future research could extend

this exploration to other sectors. Such a broader examination might shed light on sector-specific dynamics or ascertain whether similar results can be replicated in different industries.

Lastly, the SEM methodology establishes associations between variables but does not inherently prove causality. Causal interpretations should be made cautiously and ideally be supported by experimental or quasi-experimental designs. Thus, in the future, research should emphasize designing the presentation of traceability information through BCT that aligns with consumers' information preferences. To achieve this goal, qualitative research using focus groups could be a valuable method to explore precisely what kind of information consumers need to effectively assess a product's authenticity. After gaining insights from consumers, researchers can use this information to create user interfaces that effectively convey blockchain-based traceability data. This, in turn, will promote the adoption of BCT in retail and enhance the overall customer experience by providing added value.

In summary, while the present research has shed light on BCT's impact on food label systems, there exist several opportunities for future research that delves deeper, broadens the scope, and promotes deeper comprehension of this evolving field.

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italian journal of management
Vol. 42, Issue 1, 2024

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Appendix A: Measurement items

Constructs	Items	Description	Source
Performance expectancy (PE)	PE1	I find the use of blockchain in food labels to be helpful.	Venkatesh et al., 2003
	PE2	The use of blockchain in food labels is beneficial, as it allows me to be more effective in food purchasing.	
	PE3	The use of blockchain in food labels enables me to acquire information more quickly.	
	PE4	The use of blockchain in food labels speeds up the food purchasing process.	
Effort Expectancy (EE)	EE1	Learning how to use blockchain for food labeling is easy for me.	Venkatesh et al., 2003
	EE2	I find using blockchain for food labeling to be clear.	
	EE3	Using blockchain for food labeling is simple, in my opinion.	
	EE4	It is easy for me to become skillful at using blockchain for food labels.	
Social Influence (SI)	SI1	People who are important to me think that I should use blockchain labels while purchasing food.	Venkatesh et al., 2003
	SI2	People who influence my behavior think that I should use blockchain labels when buying food.	
	SI3	People whose opinions that I value prefer that I use blockchain labels when buying food.	
Facilitating Conditions (FC)	FC1	I have the necessary resources to use blockchain labels while purchasing food.	Venkatesh et al., 2003
	FC2	I have the required knowledge to use blockchain labels when buying food.	
	FC3	Using blockchain labels is something I can already do with the technologies I use while buying food.	
	FC4	There are people who can assist me if I encounter difficulties in using blockchain labels while buying food.	
Perceived Trust (TR)	TR1	I trust that using new technologies, such as blockchain, allows tracking the actual place of production of a food product.	Yeh et al., 2019
	TR2	I trust that using new technologies, such as blockchain, allows obtaining accurate information about the production process and the origin of the food product.	
	TR3	Using new ways of interaction, such as blockchain, to purchase food, makes the product more transparent in terms of the information related to its attributes.	
Perceived Product Transparency (PPT)	PPT1	By using new technologies, such as blockchain, for purchasing food products, I could fully understand the product characteristics	Zhou et al., 2018
	PPT2	By using new technologies, such as blockchain, for purchasing food products, I would have a clear idea about the product attributes.	
	PPT3	By using new technologies, such as blockchain, for purchasing food products, I would have a better understanding of the product than other traditional centralized traceability system.	
	PPT4	By using new technologies, such as blockchain, for purchasing food products, I could know the product very well.	
	PPT5	By using new technologies, such as blockchain, for purchasing food products, the product would become more transparent	
Behavioral Intention (BI)	BI1	I intend to adopt new technologies, such as blockchain, when I buy food in the future.	Venkatesh et al., 2003
	BI2	When buying food, I will always try to adopt new technologies, such as blockchain, in my daily life.	
	BI3	When buying food, I plan to continue to use new technologies, such as blockchain, frequently.	

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italian journal of management

ISSN 0393-5108
ISSN 2785-549X
DOI 10.7433/s123.2024.10
pp. 241-264

Sinergie Italian Journal of Management

Useful information for readers and authors

Aims and scope

What is the positioning of Sinergie Italian Journal of Management?

Sinergie Italian Journal of Management, the official journal of the Società Italiana di Management (SIMA-the Italian Society of Management), is a peer-reviewed scholarly publication that presents leading research across all business and management areas and focuses on the main trends and boundary-pushing ideas in management studies.

What is this journal's topic coverage?

The journal has a broad thematic profile and covers various areas in the business and management field, such as strategic management, corporate governance, entrepreneurship, international business, sustainability, small and family business, operations and supply chains, strategic communication, marketing, retailing and service management, innovation and technology management, tourism and culture management and, of course, business ethics and general management.

What is "Italian" in Sinergie Italian Journal of Management?

This journal aims both to bring the Italian management perspective to the international debate and to encourage scholars worldwide to contribute through an innovative approach on topics relevant to the sound conduct of businesses and other organisations. The journal's keywords include, but are not limited to, management applications specially relevant to the Italian economy and other mature economies, such as manufacturing, creativity, sustainability, open *Innovation,* digital transformation, entrepreneurship in small and medium-sized enterprises, family business, networks, alliances and territorial ecosystems, innovative value proposals and circular business models, as well as to the management of specific businesses, such as food, fashion, furniture, industrial equipment, art, culture, tourism, design and luxury.

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- acceptance with minor proposals for improvements
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PORTER. M. (1985), *The competitive advantage: creating and sustaining superior performance,* Free Press, New York.

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Book chapters

PHILLIPS R., BARNEY J., FREEMAN R., HARRISON J. (2019), "Stakeholder Theory", in Harrison J., Barney J., Freeman R., Phillips R. (edited by), *The Cambridge Handbook of Stakeholder Theory,* Cambridge University Press, Cambridge.

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- originalità del paper

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- framing of the research
- purpose of the paper
- methodology
- results
- research limitations
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Responsible Editor
Marta Ugolini

Registered with Law Court of Verona, Italy, reg. no. 570, 1 April 1983

20 copies printed by

GRAFICHE BAIETTA -Via Carcirago, 14, 37022 Fumane (VR) Italy - Tel. 045 770 2088
April 2024

€ 66, 00

Sinergie italian journal of management

Official Journal of Italian Society of Management
Vol. 42, Issue 1 - Jan/Apr 2024 - ISSN 0393-5108 ISSN 2785-549X

Quadrimestrale - Poste Italiane s.p.a. - Spedizione in Abbonamento Postale D.L. 353/2003 (conv. in L. 27/02/2004 n. 46) art. 1, comma 1, DCB VERONA