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Digital servitization strategies and business model innovation: The role of knowledge-intensive business services☆

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ABSTRACT

Several studies on digital servitization strategies highlight that their implementation is closely associated with some form of business model innovation. In order to engage in these innovation projects, firms need to expand their internal knowledge and skills while leveraging external organizations that support them in their servitization journey. To date, little is known about the intra-organizational factors accounting for the activation of new relationships with such knowledge-intensive service providers. This paper adopts a configurational approach for investigating the role of knowledge-intensive relationships in digital servitization strategies. Findings are founded on a multi-method investigation based on a structured survey and semi-structured interviews to Italian B2B manufacturers. The study contributes to the digital servitization literature showing the conditions that lead firms to develop relationships with different types of external providers of knowledge-intensive services, highlighting the role of firm's size, digital readiness, internal commitment, and specific hiring programs in digital servitization paths.

1. Introduction

The cluster of technologies corresponding to the fourth industrial revolution or Industry 4.0 is the new "machine" that is changing the world (Schwab and Davis, 2018). In particular, technologies such as Internet of Things, cloud platforms, data analysis, and big data have brought new life to the process of servitization that has long involved business-to-business (B2B) manufacturing (Baines et al., 2009). Moreover, developments in artificial intelligence have begun to write a new chapter in this story (Nicoletti and Appolloni, 2023; Sjödin et al., 2023). Indeed, digital technologies have led companies to explore and experiment with new and advanced combinations of products and services to offer to their customers (Kohtamäki et al., 2020). To date, several theoretical and empirical studies have focused on these digital servitization strategies highlighting that their implementation is closely associated with some form of service-based business model innovation (e.g., Chen et al., 2021; Frank et al., 2019; Paiola and Gebauer, 2020).

When engaging in innovation projects related to such strategic shift to service, firms typically must extend their internal knowledge and skills. However, they can also call on external organizations to help them in the development of their projects. While many studies on digital servitization strategies have examined their intra-organizational dimension and/or the inter-organizational one, only a few

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recent contributions have analyzed the interdependence between these two dimensions (Carloni and Galvani, 2023; Galvani and Bocconcelli, 2021; Gölgeci et al., 2022; Tòth et al., 2022). Moving in the wake of these studies, the aim of the paper is to investigate the firm-level, intra-organizational factors accounting for the activation of new relationships with external knowledge-intensive service providers through which firms can address the knowledge and capabilities need related to digital servitization projects. We approached this unanswered research question through a configurational analysis, a methodology capable of identifying one or more combinations of distinct causal factors producing the same outcome (Woodside, 2013) – in our case new knowledge-intensive relationships aimed to support digital servitization. Findings are founded on a multi-method investigation based on a structured survey and semi-structured interviews with acknowledged informants belonging to Italian B2B manufacturing firms strategically engaged in digital servitization.

The paper is organized as follows. The next section presents a selected review of the literature on digital servitization that leads to our research question. Section 3 illustrates the research methodology we followed and the empirical setting. Section 4 shows the main findings of the research, while the following section discusses them. Finally, conclusions, limitations and suggestions for further research are presented.

2. Theoretical development

2.1. Servitization, digitalization and business model innovation

Servitization, digitalization and innovation are distinct but interlinked processes as an extensive theoretical and empirical literature has shown. The servitization of manufacturing is a long-studied phenomenon (Baines et al., 2009; Khanra et al., 2021), especially about B2B manufacturing firms to signal their shift from selling products to offering more comprehensive solutions to customers' needs (Paiola et al., 2013). More specifically, firms adopting a servitization strategy move from stand-alone products and add-on services to more advanced product-service systems designed to create higher value-in-use for the customer (Kohtamäki et al., 2020; Meier et al., 2011). In other words, servitization is a service-based approach to innovation regarding what manufacturing firms offer their customers (Lafuente et al., 2023; Vilkas et al., 2022). Digitalization, which refers to the pervasive use of digital technologies to provide new value-creating and revenue-generating opportunities, alters existing socio-technical processes (Sklyar et al., 2019). Hence, it forces changes in firms, including the way they conceive and manage their offering system (Hanelt et al., 2021). Regarding servitization, the term "digital servitization" is meant to signal the new opportunities that the rise of technologies such as Internet of Things (IoT), cloud platforms, data analysis, and big data, are providing firms for positioning on the advanced frontier of servitization, experimenting with and profiting from new types of product-service systems (Gaiardelli et al., 2021; Kohtamäki et al., 2020; Paiola and Gebauer, 2020; Tian et al., 2022). Digital servitization strategies have attracted the attention of many scholars as indicated by literature reviews conducted in recent years (Agostini and Nosella, 2021; Favoretto et al., 2022; Kolagar et al., 2022a; Marcon et al., 2022; Martín-Peña et al., 2018; Paschou et al., 2020; Pirola et al., 2020; Suppatvech et al., 2019). This focus is bound to increase as the frontier of digital servitization keeps expanding with the introduction of new technological applications, particularly related to artificial intelligence (Nicoletti and Appolloni, 2023; Sjödin et al., 2023).

Several studies (Annarelli et al., 2019; Chen et al., 2021; Coreynen et al., 2017; Frank et al., 2019; Kohtamäki et al., 2019; Lerch and Gotsch, 2015; Linde et al., 2021; Paiola et al., 2022; Paiola and Gebauer, 2020; Tronvoll et al., 2020) have highlighted that – in order to exploit the opportunities arising from the combination of digital technologies and servitization by developing advanced product-service systems – it is necessary to experiment with new business models. Business model innovation means changing the essential components that make up the architecture of a business model: value proposition, i.e., what the firm offers and how it is offered; value creation, i.e., how the firm creates value using internal and external resources; and value capture or appropriation, i.e., how value proposition is converted into revenues (Clauss, 2017). In the case of the most far-reaching strategy, a manufacturer moves to outcome-based contracting where the customer pays the supplier based on the expected performance (Kohtamäki et al., 2019; Visnjic et al., 2017). In short, coming back to the interplay between servitization and innovation, digitalization brings a potential for discontinuity, which is what makes digital servitization strategies very attractive to investigate.

Interestingly, these strategies are not only affordable for large companies but increasingly also for medium and small-sized ones (Kolagar et al., 2022b; Lerch and Gotsch, 2015; Müller et al., 2018; Paiola et al., 2022). However, the design and implementation of digital servitization strategies is generally fraught with difficulties, which creates a well-observed capability divide among firms in B2B sectors (Grandinetti et al., 2020; Laudien and Daxböck, 2016; Müller et al., 2018).

2.2. Digital servitization strategies and knowledge-intensive business relationships

Successfully developing a digital servitization strategy means achieving a twofold objective: the identification of an appropriate combination of digital technologies and servitization (Gebauer et al., 2021) and the development of a new business model, with all the organizational implications it brings (Paiola and Gebauer, 2020). To achieve both goals, firms need to broaden their internal resource base by increasing knowledge and competencies in the combined field of digital technologies and service offerings, including skills that enable them to integrate with customer processes (Coreynen et al., 2017; Gebauer et al., 2021; Lenka et al., 2017; Münch et al., 2022; Sklyar et al., 2019). Scholars who have considered this issue have pointed out that the degree of newness inherent in a digital servitization strategy often leads firms, especially in the early phase of strategy development, to hire new human resources that complement existing ones bringing useful competencies and experience (Gebauer et al., 2021; Marcon et al., 2019; Nylén and Holmström, 2015; Struyf et al., 2021; Tronvoll et al., 2020). While large corporations can also meet the need for new capabilities by acquiring other

firms (e.g., specialized in digital technologies), as Gebauer et al. (2021) points out, small- and medium-sized enterprises (SMEs) must look for and succeed in recruiting skilled employees (Peillon and Dubruc, 2019; Pelletier and Cloutier, 2019). On the other hand, the option of external recruitment does not exclude that of obtaining the upgrading of internal human resources, through targeted training activities but also by leveraging internal commitment; that is, fostering the effective participation of human resources in the development of the strategy (Bustinza et al., 2018; Marcon et al., 2019; Nylén and Holmström, 2015). An additional variable that comes into play in making these choices is a firm's prior related knowledge (Coreynen et al., 2017), that is, the knowledge that a firm possesses when it starts the digital servitization project and that is related to the content of the project itself. Analyzing the role of this knowledge in digital servitization strategies, Paiola et al. (2021b) distinguished between technological prior knowledge and customer-based/service-centric prior knowledge.

To meet the need for new knowledge and competencies associated with digital servitization strategies, firms can focus on internal reinforcement in the forms discussed above and/or search for external support by collaborating with specialized knowledge holders. Again, it can be assumed that collaborations with external actors are an almost obligatory choice for SMEs (Rapaccini et al., 2023). The relevance of these relationships is generally highlighted by different and well-established strands of literature such as those drawing on the business network approach (Håkansson et al., 2009) or the open innovation paradigm (Chesbrough and Bogers, 2014). As for knowledge providers capable of supporting the innovation processes of firms, the role of knowledge-intensive business services (KIBS) has been particularly emphasized. These service providers can be distinguished by their knowledge intensity, their close interaction with their customers, and their role as problem solvers (Muller and Zenker, 2001). In addition, the knowledge that KIBS use in meeting customer needs also comes from the relationships they have with other knowledge holders (e.g., universities and other public or private research institutions), thereby functioning as knowledge brokers (Grandinetti, 2018; Shearmur and Doloreux, 2019). These peculiar features of KIBS account for their presence alongside customers engaged in particularly demanding innovation processes (Di Maria et al., 2012; Muller and Doloreux, 2009; Pereira and Vence, 2021).

Research on Industry 4.0 technologies has shown that specific external partners such as lead customers, strategic suppliers and others play no small role in the adoption of these technologies (Agostini and Nosella, 2020; Bettiol et al., 2023; Metallo et al., 2018). Studies on digital servitization strategies have also highlighted the importance that the relational view has for these strategies regarding the fact that a firm cannot move "toward digital servitization on its own – other actors also need to undergo a similar transformation", that is, digital servitization requires the development of a new business model and changes in the entire ecosystem in which the firm is embedded (Tronvoll et al., 2020, p. 302). Here, much attention has been paid, on one side of the firm's value system to suppliers of material inputs, and on the other side to customers (Favoretto et al., 2022; Freije et al., 2022; Grandinetti et al., 2020; Green et al., 2017; Huikkola et al., 2022; Kohtamäki et al., 2019; Kohtamäki et al., 2020; Marcon et al. (2022); Mosch et al., 2021; Paiola and Gebauer, 2020; Paiola et al., 2021a; Paiola et al., 2021b; Struyf et al., 2021; Vendrell-Herrero et al., 2017). Studies have also shown how KIBS can play a positive role in supporting the digital servitization journeys of B2B manufacturers and the related business model innovation (Ayala et al., 2017, 2021; Bustinza et al., 2022; Kohtamäki et al., 2019; Paiola et al., 2021b; Parida et al., 2019; Rapaccini et al., 2023).

Some recent contributions have started to investigate the interdependence between internal resources for digital servitization and relationships with external actors (Carloni and Galvani, 2023; Galvani and Bocconcelli, 2021; Gölgeci et al., 2022; Rapaccini et al., 2023; Tòth et al., 2022). For instance, adopting the business network approach and studying a single case of an Italian manufacturing company that has undertaken a process of digital servitization, Carloni and Galvani (2023, p. 15) found that "the adoption and evolution of digital servitization are characterized by a reconfiguration of internal actors and their roles and an evolving collaboration with external ones". In line with this new strand of studies, our research focuses on three aspects: the internal variables that emerged from the empirical research on digital servitization mentioned above, such as prior related knowledge or the recruitment of skilled employees; a specific category of external actors (KIBS), which a large body of literature has shown to play a relevant role in supporting firms' innovation processes; and the activation of new relationships, i.e., with KIBS that were not service providers of the firms before they started the digital servitization journey. Specifically, the research question addressed by the paper is about the intra-organizational factors accounting for the activation of new relationships with KIBS that help firms (their customers) engaged in digital servitization projects.

3. Methodology

3.1. The comparative approach and its relevance for the research

Configurational theory's foundation is that the same outcome may arise from different combinations of the same set of conditions (Greckhamer et al., 2008). Unlike regularity theory, it acknowledges and welcomes causal complexity, in the form of equifinality of different "recipes" of conditions, and causal asymmetry (Mello, 2021). Considering configurational theory a general approach taken to carrying out a given research Qualitative Comparative Analysis (QCA) is an example of methodology-specific form of data analysis, or method (King et al., 2018). In fact, QCA represents an appropriate research method when an outcome may have more than one cause (multiple causality), the causes work together to produce the outcome (conjunctive causality), and different paths may lead to the same outcome (equifinality) (Krauss et al., 2018).

QCA is a set-theoretical approach that identifies necessary and sufficient combinations of conditions for an outcome using Boolean and/or fuzzy-set algebra, in which cases are treated as configurations of defined causal conditions of a resulting outcome (Schneider and Wagemann, 2012). It responds to an overall call to move beyond the logics of pure quantitative (e.g., multiple regression) and pure qualitative analysis in different scientific fields (including management studies) raised in the last fifteen years. It welcomes asymmetric

thinking in data analysis (Woodside, 2013), and offers innovative applications of the comparative method and configurational theory (Ragin, 1987).

In fuzzy-set QCA (fsQCA) (Ragin, 2000), observed cases' data are calibrated into set membership values where 0 and 1, constitute ideal-typic boundaries of a variable (Verkuilen, 2005) and one or more crossover points (e.g., 0.5) anchor cases being "in" or "out" of a set and measure cases' membership in causal conditions and in the outcome (Schneider et al., 2010). QCA, and in particular fsQCA (Ragin, 2008), has established itself as a new useful methodological approach in different business-related research streams (Fiss, 2011; Schneider et al., 2010), particularly suitable for investigating complex subjects like innovation and servitization (Goduscheit and Faullant, 2018; Salonen et al., 2021; Sjödin et al., 2016, 2019).

3.2. Empirical context and data collection

Following well-established methods for designing exemplar investigation contexts (Seawright and Gerring, 2008; Siggelkow, 2007), we adopted a purposeful sampling process (Yin, 2009). Selected cases are: Italian B2B manufacturers; willing to participate in the research and allowing access to (current and retrospective) information coming from knowledgeable informants in different organizational functions; conveniently accessible and allowing effective research interactions; significantly investing in IoT technologies related to their final products' connectivity (being in an advanced stage of the digital services development). These criteria resulted in the final consideration of 14 B2B manufacturing companies operating in capital equipment value chains. The sample size is in line with other similar studies (Grandinetti et al., 2020; Paiola and Gebauer, 2020), and comply with the fsQCA method, whose strength is to be suitable to situations – namely between ten and fifty cases – when the number of cases is too large for traditional qualitative analysis and too small for statistical quantitative analysis (Fiss, 2011; Ragin, 2008).

We considered different criteria for methodological rigor following Gibbert et al. (2008). External validity is supported since firms differ in size and are in some of the most important Italian and European industrial clusters and regions (such as Emilia-Romagna, Lombardy, and Veneto). Data triangulation, reviews of transcripts and drafts by peers and key informants sustain internal validity and construct validity. For better reliability, interviews involved knowledgeable informants (senior managers in the business development or digital technology area), shared a semi-structured framework, and lasted approximately one hour each. They were recorded, transcribed, and coded respecting acknowledged standards (Voss et al., 2002), and were reviewed by all the authors to find a common interpretation. In line with acknowledged methodological literature (Basurto and Speer, 2012), iteratively drawing on theoretical concepts and empirical data, we open coded the content of the interviews in order to support the definition of the measures regarding conditions and outcome related to our research question. Interviews and informants' details, together with firms' basic facts, are shown in Table 1.

Table 1
Basic information regarding firms and interviews.

Company	Size[a]	Industry	BMI start	Current phase[b]	# Interviews, interviewees[c]
1	Large	Professional equipment	2014	Advanced development	2, R&D Manager, Sales Manager
2	Large	Water management devices	2018	Advanced development	2, Group Marketing Manager, IoT and Smart Solutions Manager
3	Medium	Finishing machines	2015	Advanced development	2, Service Director, Service Operation Manager, Software and IoT Solution Manager
4	Medium	Retail equipment	2014	Maturity	2, Sales Manager
5	Large	Machine tools and plants	2019	Maturity	1, IoT & HMI Manager
6	Large	Machine tools and plants	2016	Maturity	2, After Sales Manager, Innovation Manager
7	Large	Heating systems	2018	Advanced development	2, Group R&D Manager, Group IoT Manager
8	Large	Heating systems	2019	Maturity	1, R&D Manager
9	Large	Machine tools and plants	2019	Maturity	2, Head of Digital Division
10	Large	Packaging machines	2017	Advanced development	2, Service Innovation Manager, General Manager
11	Large	Machine tools and plants	2015	Maturity	2, Digital services manager, Marketing Manager
12	Large	Machine tools and plants	2015	Advanced development	2, Dvision Product Manager
13	Large	Packaging machines	2017	Advanced development	2, Digital Products and Services Manager, Automation and Digital Innovation Manager
14	Large	Professional equipment	2014	Advanced development	2, General Manager, Information Technology Manager

aMedium: <250 employees; Large: >250 employees.
bAdvanced development: the company has refined the solutions and started effective distribution and sales; Maturity: digital services had pricing, turnover and market for at least a year.
cAverage duration of each interview approximately 1 hour.

In addition to the interviews, to have data specifically complying with the selected methodology, a structured survey was distributed to the firms in order to have quantitative-like data to be elaborated with the fsQCA software in a convenient yet rigorous manner.

Combining the use of quantitative data coming from the survey and more in-depth knowledge of the cases via the qualitative interviews enables the theory-building power of fsQCA (Tóth et al., 2017). It allows a better confirmation of the results, to resolve contradictions and systematic and transparent contextualization of the differences among paths (Krauss, et al., 2018). It provides the researcher a way to "adjust the theoretically guided definitions of set anchor points by providing more detailed information on the empirical context in which the conditions and the outcome are assessed" (Basurto and Speer, 2012, p. 157). It also reinforces qualitative calibration, that in fuzzy sets substitutes quantitative variables measurement, maximizing its respondence to actual case situations and helping the balance of within- and cross-case analysis (Ragin, 2008). Table 2 reports details regarding the semi-structured interview guide and the survey.

4. Analytical elaboration and results

An overall detailed representation of the sample's firms business model innovations is reported in Table 3. Although sharing a traditional industrial manufacturing culture, the relevance of services as the main source of value in the competitive strategy is deemed at least highly important, and three firms maintain that software will be a critical component of future competition in manufacturing. Table 3 shows an interesting number of firms that aim at cross-industry solutions (five firms) and are standardizing their digital solutions as much as possible, also via modularization (eight firms). All the firms have many years of experience in developing and providing digital services and solutions (on average more than 5 years), and either have started distributing the digital services to selected customers (advanced stage of development) or have started sales for the whole market, with a defined pricing strategy and a turnover for at least a year (maturity). However, our firms register different impacts of their digital servitization strategy on the business model, where value proposition is the most impacted and value appropriation has the least impact scores of all the business model elements.

All the firms in our sample have activated new relationships with external and knowledge-intensive service providers to support their business model innovation (last column in Table 3). This result confirms in the specific case of digital servitization and related business model innovation what studies on KIBS have already highlighted in general, that is, the need for companies facing a strategic discontinuity to integrate their business network with actors carrying specific knowledge (Di Maria et al., 2012; Muller and Doloreux, 2009; Pereira and Vence, 2021). In our sample, the number of these new relationships range from 1 to 6 with an average of 3.2. They involve KIBS such as platform services providers (such as cloud connectivity), digital platform technology providers (e.g., data-based solutions and suites), digital integrators and software implementors (large technology suppliers, regional partners, or independent software providers), strategy and organization consultants, and research centers or similar university-related actors.

Given the value that these connections have for business model innovation highlighted in the theoretical section, our investigation aims to understand at what conditions firms establish these valuable links with external KIBS, i.e., what factors related to the firms (the intra-organizational side of digital servitization) affect the activation of new knowledge-intensive relationships (the inter-organizational side).

Being a configurational approach a proper method for linking deductive theory-based reasoning and inductive empirically founded evidence (Boswell and Brown, 1999), we employed the extant literature reviewed in subsection 2.2 to identify possible causal factors of the outcome variable (new relationships with KIBS) and inductively explored how they are reflected and complemented by other variables in case-based contextual situations. We therefore iteratively confronted theory and empirical data coming from the survey and the interviews to refine our model. The fsQCA analytical elaboration ultimately highlighted the influence of the following internal factors on manufacturing companies' activation of new knowledge-intensive relationships supportive of digital servitization:

Table 2
Interview guide and survey details.

Interview guide subjects	The semi-structured interview guide is composed of four parts, encompassing the respondent's profile (professional history and career, current role and responsibilities), the digital servitization project (initiation and evolution, organizational units and internal resources involved, market response and installed base, marketing and sales management, revenue model), the ecosystem (partners-suppliers selection and contribution, relationship governance, technological solutions adopted, specific new relationships activated), future changes and evolutions.
Survey topics	The survey was designed with particular care in order to be thoroughly usable given the chosen methodology, maximizing closed questions using numeric scales (mainly Likert-type scales). It was composed of five sections covering conditions and outcome and encompassing the following subjects. 1) Strategy and digitalization: relevant basic information related to firm's competitive strategy, importance of services in the strategy, use of I4.0 technologies, digitalization level and readiness. 2) The digital servitization project: promoters, start year and evolution phase, # of connected devices, role of key/pilot customers. 3) Digital service offering: number and type of digital services offered to the market, evaluation of the impact of digital services on the firm's BM (value creation, value proposition, value distribution, value capture). 4) Internal resources for digital servitization: internal people involved in the digital servitization, their area of contribution, the levels of internal commitment, participation and resistance. 5) External relationships: number and type of external relationships specifically activated for the project, type of relationship governance, relevant changes for the future.

Table 3
Firms and business model innovation details.

#	Service strategic relevance[a]	Source of value in the future	Digital readiness[a]	Project duration (years)	Scope of digital services	BMI impact[b]	Internal resistance	Internal capabilities[a]	Specific hirings (#)	New service relationships
1	High	Products and services	High	8	Industry-specific	VC, VP	Post-sales	Low	0	1
2	Extremely high	Products and services	Very high	4	Industry-specific	VC, VP, VD, VA	No resistance	High	2	5
3	High	Products and services	Medium	7	Cross-industry	VC, VP, VD	R&D	Low	2	4
4	Extremely high	Services	High	8	Industry-specific	VC, VP, VD, VA	R&D	High	0	4
5	Extremely high	Products and services	Very high	3	Cross-industry	VC, VP, VD	Sales	Low	1	3
6	Extremely high	Software and services	High	6	Industry-specific	VC, VP, VD	Sales	Medium	5	1
7	Extremely high	Products and services	Medium	4	Industry-specific	VC, VP, VD, VA	No resistance	Very high	5	6
8	Extremely high	Services	Medium	3	Industry-specific	VC, VP, VD, VA	Post-sales	High	1	4
9	Extremely high	Software and services	High	3	Industry-specific	VC, VP, VD	Sales	Very high	2	1
10	Extremely high	Services	Very high	5	Cross-industry	VC, VP, VD, VA	Sales	High	1	4
11	High	Products and services	Medium	7	Cross-industry	VC, VP	Sales	High	5	5
12	Very High	Products and services	Very high	7	Cross-industry	VC, VP, VD, VA	Sales	Very high	5	4
13	Extremely high	Products and services	High	5	Industry-specific	VC, VP	Sales	Very low	3	1
14	Extremely high	Software and services	Very high	8	Industry-specific	VC, VP, VD, VA	Sales	Very high	6	2

aLikert scales are graded as follows: 1: not relevant or null; 2: very low; 3: low; 4: medium; 5: high; 6: very high; 7: extremely important.
bBMI: Business Model Innovation; VC: Value creation; VP: Value proposition; VD: Value distribution; VA: Value appropriation.

a. the firms' size,
b. the presence of valuable extant capabilities, in particular the firm's digital readiness,
c. the overall participation of the firm's useful capabilities to the new project (internal participation),
d. the acquisition of specific new competencies (via hiring of dedicated employees).

In the following subsections, codification and calibration of each of the above-mentioned variables will be described in detail, to further describe their nature of causal conditions and argument their influence on the outcome variable.

4.1. Variables codification and calibration

Table 4 describes meanings, attributes, and details of the calibration procedure of the above-mentioned variables. All the causal conditions indicated were codified and calibrated following acknowledged procedures, also considering the in-depth knowledge of the firms' specificities due to the qualitative investigation. We complied with the recommendations provided by Basurto and Speer (2012) and Tóth et al. (2017) regarding calibration and in particular the calibration of qualitative data, and acknowledged the challenges faced by researchers in mixed methods research process (Sandelowski, 2000). As recommended in de Block and Vis (2019), we developed a coding scheme to assign codes for the outcome and the conditions. We calibrated our conditions based on various primary and secondary data, also resolving small coding contradictions via a final stage of recalibration (Verweij, 2015).

As suggested by Basurto and Speer (2012), we constructed ideal-typical cases to assess full membership or non-membership of conditions and outcome. Inductively, we also explored significant gaps in the data and their measures of fit to look for potentially deviant cases and logical remainders relevance. We also followed recommendations by Fischer (2014), Kim and Verweij (2016), and de Block and Vis (2019) in relation to the necessity of including tables and explain the motivations of the condition calibration and relevant details in the research process. We finally provided a robustness measurement in the form of a sensitivity test as part of a rigorous fsQCA study, dropping or adding cases and conditions, altering consistency thresholds, using alternative measures for a concept (Basurto and Speer, 2012; de Block and Vis, 2019; Kirchherr et al., 2016; Schneider and Wagemann, 2012).

Following these recommendations, we operationalized the factors that affect the configurational analysis and calibrated them, mixing crisp and fuzzy modes. A similar use of mixed crisp and fuzzy variables and fuzzy output can be found in Bustinza et al. (2022). Set membership scores expressing cases belonging to a certain set with specific properties or features (conditions) are used to operationalize the variables, with scores of 0.00 = full non-membership and 1.00 = full membership (Basurto and Speer, 2012) and intermediate values for fuzzy sets. The in-depth theoretical and substantive knowledge of the researchers is fundamental in this calibration activity (Ragin, 2008): crisp or fuzzy values are attributed to each firm based on the value of each condition, also considering the frequency distribution of the original variables coming from the survey's dataset.

As shown in Table 4, values have been assigned to conditions and variables as follows. DIGIREAD is a crisp variable that refers to the existence of a valuable level of prior knowledge and capabilities necessary for digital servitization. It is related to the firm's digital readiness, calibrated accordingly to the variable's distribution (AVG, MED, MODE = 5). The calibration is fully in [1] in case of high levels of digital readiness (values equal or above 5), and fully out [0] for values below 4. PEOPLENEW is a fuzzy variable indicating the condition in which a relatively high number of people is newly hired specifically for the project. The original numeric data in the survey is calibrated in a fuzzy mode, with values as follows: no people hired, fully out [0]; 1 or 2 people, more out than in [0.3]; 3 or 4 people, more in than out [0.7]; 5 or 6 people, fully in [1]. INTPART is a crisp variable indicating a high level of participation of the available internal skills in the project of digital servitization. The original 1–7 Likert scale is calibrated following the distribution of the sample (Avg: 4.57; Median, Mode: 5) as fully in [1] when the original value is equal or higher than 5, and fully out [0] in the other

Table 4
Variables description and calibration.

Variable type	Variable name	Variable meaning	Description	Calibration*
Conditions	DIGIREAD	Digital readiness of the company	Valuable level of use of instruments and software like ERP, MES, CRM, workflow management, meeting platforms) (Likert scale 1–7)	<4 = 0 >=4 = 1
	PEOPLENEW	High number of people newly hired for the project	Relevant number of new people hired specifically for being part of the team in charge of the innovation (numerical item)	No people hired: Fully out [0]1,2 people: more out than in [0.3]3,4 people: more in than out [0.7]5,6 people: fully in [1]
	INTPART	High level of commitment in the project	High level of commitment and participation of the available internal skills in the project of digital servitization (Likert scale 1–7).	<5 = 0 >=5 = 1
	SME	Small- to medium-size of the companies	Based on UE size classes: 1 Micro-enterprise (<10 employees)2 Small enterprise (<50 employees)3 Medium enterprise (<250 employees)4 Large enterprise (>250 employees)	1,2,3 =1 4 = 0
Output	NEWREL	High number of new ad-hoc external relationships	Total number of new relations with external suppliers specifically initiated for digital servitization (numerical item)	No new relations: Fully out [0]1,2 new relations: more out than in [0.3]3,4 new relations: more in than out [0.7]5,6 new relations: fully in [1]

* The variables' frequence distribution has been thoroughly considered to fix the optimal threshold level

cases. SME is a crisp condition regarding firms' size, following the UE scale based on the number of employees. We finally calibrated as fully in [1] companies with less than 250 employees, and fully out [0] all the other cases. NEWREL is our output variable, indicating a high total number of new relations with external KIBS. It is calibrated in a fuzzy mode on the base of the original numerical field of the survey (AVG: 3.2) as follows: no new relations, fully out [0]; 1 or 2 new relations, more out than in [0.3]; 3 or 4 new relations, more in than out [0.7]; 5 or 6 new relations, fully in [1].

Table 5 reports the fsQCA data frame, that is the calibrated values assigned to cases in relation to conditions and the output variable.

4.2. Preliminary elaborations and necessary conditions

To detect meaningful correlations among variables and eliminate redundant ones, we performed a bivariate correlation analysis using SPSS 28, that detected no significant correlations. Therefore, we proceeded with the analysis of the model:

NEWREL = f(SME, DIGIREAD, INTPART, PEOPLENEW)

based on the data frame shown in Table 4. Elaborations and truth tables are performed with Ragin's fsQCA 3.0 software (Ragin and Davey, 2017), currently the standard software choice for fsQCA and adopted in several relevant studies (Bustinza et al., 2022; Schneider et al., 2010; Sjödin et al., 2016, 2019; Woodside, 2013).

The analysis of necessary conditions is the first step in fsQCA (Ragin, 2008). The result of this specific analysis (Table 6) shows that no condition has a consistency score above the requested threshold of 0.9 for being necessary for the outcome (Schneider et al., 2010). However, DIGIREAD with a consistency of 0.885057 and ~SME (the symbol ~ indicates negation) with a consistency of 0.839081, appear to be very important conditions. In both cases coverage is above 0.50 as recommended by Mello (2021).

4.3. Identification of sufficient conditions and truth table analysis

Tables 7 and 8 report the output of the sufficiency test, showing the complete truth table and the solution emerging from the truth table analysis.

Table 7 shows the truth table derived from the fsQCA algorithm applied to our sample. It shows the number of logically possible combinations (configurations, or paths – in row) of conditions included in our study capable of explaining the outcome. Combinations with no cases lack empirical foundation and are to be omitted.

Analytic findings are judged based on coverage (proportion of membership in the outcome explained by the identified configurations) and consistency (extent to which the presence of the supposedly sufficient configurations produces the outcome) that range between 0 and 1 (Krauss et al., 2018). Configurations with at least one case and a consistency above 0.8 are considered meaningful, following standard fsQCA procedures.

The solution's overall consistency should reach at least 0.75 (Ragin, 2008), while for a proportional reduction in inconsistency each solution should meet a threshold of 0.70 (Greckhamer et al., 2008). As shown in Table 8, our analysis fully satisfies these requirements. Although not very high, solution coverage (47 %) is satisfactory, since there is no commonly agreed minimum coverage a fsQCA must reach in current best practice, and well-known studies show rather lower coverage: for example, solutions in Fiss (2011) account for about 27 % of membership in the group achieving the output.

4.4. Interpretation of fsQCA results

The intermediate solution of the truth table analysis is reported in Table 8. Our model identifies three equifinal configurations, three alternative paths conducting to our outcome variable (NEWREL):

1. SME *(and)* DIGIREAD *(and)* ~INTPART *(and)* ~PEOPLENEW

Table 5
Data frame.

#	SME	DIGIREAD	PEOPLENEW	INTPART	NEWREL
1	0	1	0	0	0,3
2	0	1	0,3	1	1
3	1	1	0,3	0	0,7
4	1	1	0	1	0,7
5	0	1	0,3	0	0,7
6	0	1	1	0	0,3
7	0	1	1	1	1
8	0	1	0,3	1	0,7
9	0	1	0,3	1	0,3
10	0	1	0,3	1	0,7
11	0	0	1	1	1
12	0	1	1	1	0,7
13	0	1	0,7	0	0,3
14	0	1	1	1	0,3

Table 6
Analysis of necessary conditions.

Outcome variable: NEWREL		
Conditions tested	**Consistency**	**Coverage**
DIGIREAD	**0.885057**	0.592308
~DIGIREAD	0.114943	1.000000
SME	0.160920	0.700000
~SME	**0.839081**	0.608333
INTPART	0.660870	0.584615
~INTPART	0.339130	0.433333
PEOPLENEW	0.620690	0.720000
~PEOPLENEW	0.586207	0.784616

Table 7
The complete truth table for the outcome.

SME	DIGIREAD	INTPART	PEOPLENEW	# of cases	Cases	Raw consist.	PRI consist.	SYM consist.
1	1	0	0	1	3	1	1	1
0	0	1	1	1	11	1	1	1
0	1	1	0	4	2, 8,9,10	0.857143	0,789474	0.789474
0	1	1	1	3	7, 12, 14	0.761905	0.62963	0.809524
1	1	1	0	1	4	0.7	0.571429	1
0	1	0	0	2	1, 5	0.65	0.363636	0.5
0	1	0	1	2	6, 13	0.45	0	0
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0
1	0	1	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0
1	0	0	1	0	0	0	0	0
1	1	0	1	0	0	0	0	0
1	0	1	1	0	0	0	0	0
1	1	1	1	0	0	0	0	0

Table 8
Truth table analysis (intermediate solution).

	Raw coverage	Unique coverage	Consistency
SME*DIGIREAD*~INTPART*~PEOPLENEW	0.0804598	0.0804597	1
~SME*DIGIREAD*INTPART*~PEOPLENEW	0.275862	0.275862	0.857143
~SME*~DIGIREAD*INTPART*PEOPLENEW	0.114943	0.114943	1
Solution coverage: 0.471264			
Solution consistency: 0.911111			
Model: NEWREL= f(SME, DIGIREAD, INTPART, PEOPLENEW)			
Algorithm: Quine-McCluskey			
Frequency cutoff: 1; consistency cutoff: 0.857143			
Cases with greater than 0.5 membership in terms:			
SME*DIGIREAD*~INTPART*~PEOPLENEW: 3 (0.7,0.7)			
~SME*DIGIREAD*INTPART*~PEOPLENEW: 2 (0.7,1), 8 (0.7,0.7), 9 (0.7,0.3), 10 (0.7,0.7)			
~SME*~DIGIREAD*INTPART*PEOPLENEW: 11 (1,1)			

2. ~SME *(and)* DIGIREAD *(and)* INTPART *(and)* ~PEOPLENEW
3. ~SME *(and)* ~DIGIREAD *(and)* INTPART *(and)* PEOPLENEW

Path 1, that accounts for a total coverage of 8.0 %, entails conditions related to the small to medium size of the firms (medium-sized firms in our sample) and the existence of a digital readiness, together with the absence of a high internal participation to the project and the absence of a relevant number of new hirings associated to it. It shows that one recipe regards medium firms that can leverage on a sufficient prior digital capability but cannot boast a relevant internal involvement of existing capabilities and the possibility to hire new specific professionals dedicated to the new project.

Path 2, that with a coverage of 27.6 % is the most representative, entails conditions related to large size of the firms, a sufficient level of digital readiness and a high level of internal participation, together with a low number of new dedicated hirings.

Path 3, that accounts for a 11.5 % of coverage, also regards large firms. In this case they are not sufficiently digital ready, while having a high internal participation in the project and a high number of specific hirings for the project.

Paths 2 and 3 together account for almost the 40 % of the coverage and represent the largest part of the solution's cases in the

sample. Notwithstanding they both show a high internal commitment, paths 2 and 3 differ in the most relevant condition of our model (DIGIREAD, consistency.885057): in path 2 a high digital readiness associates with a high internal participation, while in path 3 firms must deal with a low digital readiness also by resorting to external recruitment. Both paths regard non small- to medium-sized firms: this echoes the above-mentioned very high consistency level of the condition ~SME, indicating that not being an SME is relevant for developing new knowledge-intensive relationships in order to support digital servitization.

5. Discussion

Table 9 describes the paths belonging to our truth table analysis' solution. It confirms the relevance of some of the conditions we described in the theoretical and methodological sections: the size of the firm (Grandinetti et al., 2020; Kolagar et al., 2022b; Laudien and Daxböck, 2016; Lerch and Gotsch, 2015; Müller et al., 2018; Paiola et al., 2022; Peillon and Dubruc, 2019; Pelletier and Cloutier, 2019); the importance of prior knowledge and capabilities, especially digital readiness (Coreynen et al., 2017; Paiola et al., 2021b); the participation of the firm's internal capabilities to the business model innovation (Bustinza et al., 2018; Marcon et al., 2019; Nylén and Holmström, 2015; Rapaccini et al., 2023); the acquisition of new capabilities via specific hirings (Gebauer et al., 2021; Marcon et al., 2019; Nylén and Holmström, 2015; Struyf et al., 2021; Tronvoll et al., 2020).

As detailed in the findings section, having the first two conditions –firms' size and prior digital knowledge– very high consistency levels, they approach the status of necessary conditions. Thus, they play a crucial role in our configurational analysis. Regarding firms' size, path 1 refers to medium-sized firms, while paths 2 and 3 refer to larger firms. As far as prior digital knowledge is considered, paths 1 and 2 regard digitally ready firms, while path 3 is related to non-digitally ready ones.

Findings from the configurational analysis complement in several respects our knowledge of the interdependence between internal resources employed by firms in their digital servitization strategies and their access to external resources via inter-firm relationships (Carloni and Galvani, 2023; Galvani and Bocconcelli, 2021; Gölgeci et al., 2022; Tòth et al., 2022), at least as far as the relationships with KIBS are concerned (Rapaccini et al., 2023).

Firstly, previous works underlined the role of prior knowledge related to technological developments and acquaintance of markets in gaining early sales advantages in technology-related entrepreneurship (Marvel and Droege, 2010). This was echoed by recent studies on digital servitization strategies (Coreynen et al., 2017; Paiola et al., 2021b) highlighting the relevance of available prior knowledge related to digital technologies (digital readiness). We added to this stream of research providing empirical evidence of the link between digital readiness and the search for external support. Indeed, the overall importance of the paths that involve a sufficient level of digital readiness (around three quarters of the cases involved in the solution) testifies for the centrality of an adequate digital preparation of the firms for being able to manage strategically fruitful relationships with external knowledge-intensive providers. This result is consistent with the findings from studies that have delved into the KIBS-customer relationship (e.g., Miles, 2012), i.e., the service provider essentially acts as a problem solver and the performance of this activity is strictly dependent on the quality of the interaction with the customer, which in turn depends on the latter's prior knowledge.

Notably, in the configuration with the highest coverage (path 2), digital readiness is connected to another condition, that is, the participation of firm's human resources to the digital strategy. Previous studies showed the importance of internal participation and commitment for the success of digital servitization strategies (Bustinza et al., 2018; Marcon et al., 2019; Nylén and Holmström, 2015; Rapaccini et al., 2023). Our findings indicate that this factor complements prior related knowledge to form a recurring pair of internal conditions in KIBS-assisted cases of digital servitization strategy. This result reinforces the idea that the use of an external knowledgeable actor does not exempt a company facing a complex strategy from making the necessary investments in knowledge and promoting broad internal participation in strategy implementation.

Our evidence shows that low levels of digital readiness appear only in combination with a high level of internal involvement and a

Table 9
Configurations of the outcome variable (intermediate solution).

Conditions	Path 1	Path 2	Path 3
Small to medium size	●	⊗	⊗
High digital readiness	●	●	⊗
High internal commitment	⊗	●	●
High number of hirings	⊗	⊗	●
Consistency	1	0.857143	1
Raw coverage	0.0804598	0.275862	0.114943
Unique coverage	0.0804597	0.275862	0.114943
Covered cases / Unique covered cases (Bold)	**3**	**2, 8, 9, 10**	**11**

Note: Black circles indicate the presence of a condition, crossed out circles its absence

high number of specific new hirings (path 3). Previous studies have pointed out that: digitally based business model innovation is a complex process; the firm facing it often suffers from knowledge gaps; to close them, it must search externally and internalize skills not available internally (Gebauer et al., 2021; Marcon et al., 2019; Nylén and Holmström, 2015; Struyf et al., 2021; Tronvoll et al., 2020). Our results suggest that the combination of a recruitment plan and an effort towards high internal participation is equifinal to the one discussed above – digital readiness combined with internal participation – for making fruitful the interaction with a service provider carrying specialized knowledge and skills complementary to those (now) present within the firm.

Both discussed combinations feature as an invariant condition a high level of internal commitment that is associated with an appropriate stock of knowledge and skills, either already accumulated in the past (path 2) or to be completed through targeted hiring (path 3). Moreover, both combinations were only found in large companies. The existing literature maintains that digital servitization strategies are not precluded for SMEs (Kolagar et al., 2022b; Lerch and Gotsch, 2015; Müller et al., 2018; Paiola et al., 2022), but also points to relevant barriers that hinder them (Grandinetti et al., 2020; Laudien and Daxböck, 2016; Müller et al., 2018). Consistently, our research discovered only one configuration concerning SMEs (the one with the lowest coverage). In this case, the firm succeeds in taking the digital servitization journey thanks to the related knowledge accumulated in the past and the support provided by the interaction with external KIBS firms.

To improve the discussion, we enrich the evidence coming from the survey analysis with the information gathered in the in-depth interviews to the firms. This allows us to comment and give more depth to the results, adding details regarding firms' strategies and fine-grained data related to the matter investigated. In so doing, we can eventually postulate some propositions regarding the configurations we found.

In our first configuration (SME *(and)* DIGIREAD *(and)* ~INTPART *(and)* ~PEOPLENEW), the medium size of the firm, the digital readiness, the low internal participation, and the low hiring activity are conditions that lead to high level of relational activity with external knowledge-intensive providers. This first path is the only configuration specifically involving the smaller firms of our sample. In particular, low internal participation is associated with the limited slack human resources possessed by these firms, condition that generally hinders the most radically innovative behaviors in SMEs (Rapaccini et al., 2023). As company 3's Service Operation Manager points out: *"We are not structured enough to manage complex data-based contracts. We find it hard to think of structuring a monitoring service based on our remote assistance service in which there is a need for control personnel, a control room, because there are only four to manage the whole system and there are no people to do this service continuously."*

This path refers to *KIBS-assisted medium-sized innovators*. They are aware of the difficulty of the journey (Paiola et al., 2021b), and of the relevance of digital readiness for using technologies in business model innovation. In other terms, they acknowledge Müller et al.'s (2018) observation that "fortune favors the prepared". At the same time, they perceive the constraints arising from their size: the skills they have are already overwhelmed; they are not able to invest in new skilled human resources, also in relation to the uncertainty surrounding their digital servitization project; they have a limited capacity of attract digitally related capabilities that are costly and much contended in the market. In the face of these shortcomings, opening to external relationships appears as a fruitful choice, given that external knowledge-intensive digital providers may fruitfully accompany non-large firms in their business model innovation. They assist these firms in designing and implementing their innovation journeys, providing an articulated set of valuable contributions not limited to technological solutions and digital artifacts, but encompassing more organizational- and managerial-related matter that complement and substitutes internal capabilities (Rapaccini et al., 2023).

The preceding arguments supports the following proposition:

[P1]: Medium-sized, digitally ready manufacturers pursue digital servitization resorting to new relationships with KIBS, that assist them to mitigate their low levels of internal participation and limited hiring capacity.

Our second configuration (~SME *(and)* DIGIREAD *(and)* INTPART *(and)* ~PEOPLENEW) adds further elements to the model. This path has the highest coverage and therefore is the most representative. We named this path *large externalizing innovators* for it links the outcome variable to the large size of the firms, the high digital readiness, the high level of internal participation, and the limited recruiting activity. In the words of company 9's Head of Digital Division: *"Our philosophy is aimed at being agile and flexible. We rely above all on the partnership with some external suppliers who give us the digital elements and structural solutions we need to enable the service. Internally, recruitments are few and aimed at key figures capable of designing the service and interfacing with the ecosystem, because we are aware of the specificity of the construction skills of digital solutions and of the scenario of convergence and standardization that will inevitably be the near future. In general, the corporate commitment is high but … participation must be built day by day with constant and patient cultural action."*

The low hiring activity is in line with the perspective of focusing on the core business. These firms need to have people capable of strategically coordinating internal and external activities, but not to internalize operations related to the development and implementation of the architectures and the software for digital servitization. They closely observe technological evolutions and are prone to seize opportunities given by new digital solutions and platforms offerings that can be adopted for improving their digital services. This requires an internal focus on understanding digital architectures and basic technological choices that fit their service strategy. Therefore, they avoid excessive internalization of digital resources and capabilities, but instead dynamically seek external service providers who can be suitable partners for this strategy, carefully choosing the solution-partner pairing in a mix tailored to their needs based on what is marketed by international players, local third parties, and local startups.

This configuration is particularly suitable for companies with organizational structures highly focused on defined industries and limited possibilities for strategic replication of technological solutions underlying their digital servitization journey (Paiola et al., 2022). These companies can also be multi-unit firms but with limited opportunities for standardization and reuse of solutions from business to business, thus developing and implementing highly effective vertical solutions for their clients (Paiola et al., 2021a).

This configuration supports the following proposition:

[P2]: Large, digitally ready and focused manufacturers with high internal participation and limited hirings effectively pursue digital servitization leveraging on new relationships with KIBS acting as specialized digital outsourcees.

We named our third configuration (~SME *(and)* ~DIGIREAD *(and)* INTPART *(and)* PEOPLENEW) *large internalizing innovators*. Like the previous path, the outcome of new knowledge-intensive relationships also regards large firms with a high internal participation. However, in this case firms show little digital readiness and a relevant specific hiring activity. Here, the capability gap that may create difficulties to the manufacturing firm involved in digital servitization is faced by rich and various relations with external KIBSs that help firms providing digital solutions and provide technology-related services and consultancy (Rapaccini et al., 2023).

Firms following this path strive as much as possible to involve suitable internal resources and significantly invest in technologies and hirings. Despite their relative lack of digital preparedness, they see a broad-spectrum application of the digital servitization perspective for the company. These are multi-unit companies that have significant technological correlations among the different businesses they handle, and therefore approach digital servitization as a business model innovation that comprehensively addresses the group's activities. They view the innovative project as the initial core of an internal division focused on serving as a specialized and competent unit the digital servitization processes of the subunits. The solutions developed are therefore of a general-purpose nature, compatible with the minimal verticalization required for the market/market segments of reference. The company aims to create the reference enterprise solution, which can be subject to a limited degree of customization for specific needs of relevant market segments at the business unit level.

Their approach with external KIBS, which are crucial for their innovative journeys, differs from that of path 2. Here, activities related to software development and maintenance as well as other ongoing digital activities provided by external firms, are internalized and entrusted to newly established digital teams that become increasingly structured over time. Given the limited average attractiveness of manufacturing firms as place of work, this can also lead to the creation of new specific business units via equity investments in existing technology-related companies. Alongside, relationships with local or regional providers of knowledge intensive services, that initially enable the digitally based business model innovation, gradually give way to fewer relationships with major technology suppliers, from whom architectures are acquired, adapted, and implemented internally. This choice also serves the purpose

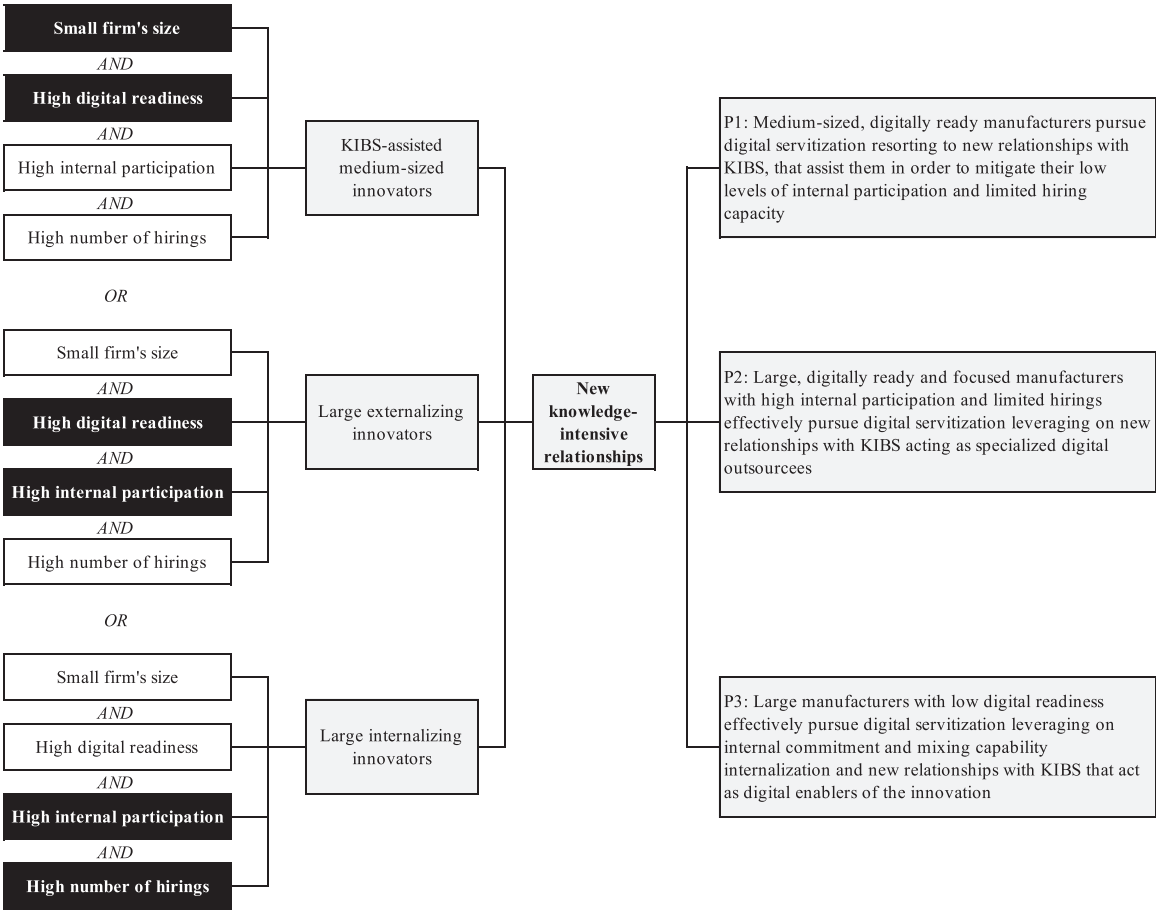

Fig. 1. Configurational model of new knowledge-intensive relationships in digital servitization strategies. *Adapted from* Goertz and Mahoney (2005) *and* Bara (2014). Note: Black boxes indicate the presence of a condition, white boxes its absence. Legend: logical AND: conjunction of conditions; logical OR: substitutable/equifinal paths. Connecting lines indicate sufficient relationships in the model and logical relation with propositions.

of internalizing data analysis and data value protection in the future, given that the weight of big data gradually becomes more significant. In the words of company 11's Digital Service Manager: *"Digital services on machines hold a great complexity for us and it is also growing with the increasing adoption of the solutions by our customers … The more we increase the fleet of connected machines, the more we have to increase our ability to respond to new service requests, that is to put more people to work in terms of support, data analysis, solution design … We can do this job, but we need also help from the outside to do the job and to learn how to do it…"*.

This path supports the following proposition:

[P3]: Large manufacturers with low digital readiness effectively pursue digital servitization leveraging on internal commitment and mixing capability internalization and new relationships with KIBS that act as digital enablers of the innovation.

Both configurations that characterize large firms point to the crucial importance of human resources in their digital servitization strategies. In this regard, it is worth mentioning the general difficulty experienced during the servitization journey in capturing the value corresponding to the value proposition of the new business model. As emerged from the in-depth interviews, the obstacles in monetizing the investments are also due to the action of internal resistance, mainly in the sales department. Large companies have addressed this weakness by increasing the involvement of internal employees in the digital servitization projects or by hiring new people in the projects, with the aim of inserting new competencies.

Fig. 1 illustrates the configurations emerging from the findings as described in the discussion, linking them to the propositions related to new knowledge-intensive relationships in business model innovation.

6. Conclusions and implications

Recent studies have highlighted the interdependence between internal resources for digital servitization and inter-firm relationships (Carloni and Galvani, 2023; Galvani and Bocconcelli, 2021; Gölgeci et al., 2022; Rapaccini et al., 2023; Tòth et al., 2022). Starting from this premise, out paper has focused on the intra-organizational conditions that lead firms involved in digital servitization to activate new relations with providers of technological and organizational services and solutions (KIBS).

Against this background, this study innovatively applied a configurational approach to demonstrate that business model innovations related to digital servitization feature equifinal paths to the outcome of new knowledge-intensive relationships involving a specific set of sufficient conditions. The paper holds both theoretical and managerial implications, contributing to the stream of business model innovation in manufacturing firms by adding new empirical elements of the knowledge-intensive relationships requested by innovative and possibly disruptive service-based transformations in manufacturers' business models led by digitalization and IoT technologies.

6.1. Theoretical contribution

Our research confirms previous studies and provides some original and theoretically relevant findings about the intra-organizational factors accounting for the activation of new relationships of manufacturing firms engaged in digital servitization strategies with KIBS.

First, our findings confirm that firm's size matters in digitally enabled business model innovations (Kolagar et al., 2022b; Lerch and Gotsch, 2015; Müller et al., 2018; Paiola et al., 2022). Although our sampling cannot boast statistical representativeness, the study adds to previous research evidence showing that the number of SMEs that are in advanced development phases of their business model innovation is far lower than that of large firms (Grandinetti et al., 2020; Paiola et al., 2022). Our evidence show that only most advanced and digitalized medium-sized manufacturing firms can play a role in the digital servitization scenario, and they can achieve that also resorting to beneficial relationships with external KIBS. Providing both technological and managerial contributions, KIBS enable non-large manufacturers to overcome traditional challenges they encounter in digital servitization processes, related to their limited slack human resources and hiring capacity. External relationships help these digitalized innovators to close internal capability gaps and to activate digitally based solutions that have significant impact on the business model, enabling its progress to advanced stages of maturity.

Second, for large firms, our evidence shows that internal participation is always a relevant condition for an appropriate involvement of the firm in the project, while the level of digital readiness leads to identify two diversified paths. Bearing in mind that either way the technological and strategic novelty of digital servitization requires to establish relationships with specialized knowledge-intensive actors (Tronvoll et al., 2020), firms' digital readiness makes the difference between large and digitally ready firms that can focus on internal commitment and large and non-digitally ready firms that fill their gap by resorting to the recruitment of specific skills. More precisely, for non-digitally ready large firms, mature digital servitization projects show a strong relationship between the leveraging of internal capabilities and specific hiring activity with our outcome variable. In short, digital readiness appears to play a critical role in digital servitization, representing an overarching and contextual quality of the firm that reduces the cognitive distance from the business-as-usual product-based logic and the new business model orientation in which services, data and performances (not products) will be core. This envisions a capability divide that the disadvantaged firms can overcome through the dynamic interplay of extant capabilities and new hirings that we have observed.

Third, our research shows that leveraging KIBS contribution in digital servitization relates to complex processes of and dynamic approaches to internal capability development. Specifically, different processes and approaches lead to different roles of KIBS in digital servitization, namely: assist (smaller) firms in their business model innovation journeys, providing technological and managerial contributions to their innovations (path 1); act as specialized and stable outsourcees of digital solutions (path 2); enable the business model innovation of firms that in time internalize digital competencies (path 3).

Finally, the interdependence between internal resources utilization and collaboration with KIBS underlines the increasing importance of the ecosystem perspective also in capital equipment manufacturers digitalization: in some cases, the development of the inter-organizational relational activities of our firms envisions future changes in their business ecosystem that is similar to what has been described elsewhere (Jovanovic et al., 2022; Kohtamäki et al., 2019; Kolagar et al., 2022b; Sklyar et al., 2019).

6.2. Managerial implications

The theoretically relevant results of the paper have specific managerial implications. First, medium-sized digitalized innovators aiming at innovating their business model via a consistent digital servitization should carefully search for the right external partner(s) that allow them to overcome their resource limitations, avoiding independent initiatives that may result overly ambitious and ineffective. New relationships in this case should target external partners able to provide a complete set of technological and organizational contributions, or act as orchestrators with other ecosystem actors in that direction.

For larger innovators, our evidence underlines that internal participation is an important condition for successfully manage the complexity of such business model innovations and effectively interact with external partners that provide innovative knowledge and capabilities. Digitally ready innovators should therefore search and select the right strategic partner(s) to develop the project, carefully mixing external contributions with relevant internal capabilities related to the overall digital service solutions design and partner selection ability. These proactive and managerially advanced firms indicate a consistent alignment of their relational strategies with the likely future scenario of a full digitalization of manufacturing products and services. They acknowledge that their priority is in new data-based service design and not in the technology of the solutions per se, that will become increasingly standardized and integrated within and across industries. Especially when focalized on relatively narrow markets and specialized industries, they better focus on value distribution and value capture, emphasizing the design of service-related value offerings enabled by digital solutions rather than on the design of the digital solution itself. Therefore, they should adopt an open approach to external KIBS participation, willing to dynamically select and establish knowledge intensive relationships that fit market and technological evolution.

Specific hirings and knowledge-intensive relationships with external actors should be managed accordingly for non-digitally ready larger innovators. Especially in the case of diversified corporations with several technological and market related business units, the advantages of replicating digital investments through standardization is evident and correctly suggests internalizing their management in dedicated organizational units. In our cases this internalization strategy is more common after a first adaptation and acclimation period, characterized by intense environmental exploration activities by one or few selected internal managers or employees followed by intense hirings. Here, large firms may adopt a rather closed approach to digital servitization, aimed at leveraging external contributions as enabling experience for sustaining an overall internalization strategy. Managers following this line should constantly monitor its fit with technological and market related evolution, since accumulated stocks of knowledge will rapidly decrease their competitive contribution in overcrowded and demanding markets, and extant internal capabilities may become insufficient.

The potential disruptiveness of digital servitization and its impacts on manufacturing business model discontinuity in the future suggests that both consciousness and courage must drive top managers and entrepreneurs to embrace the change and be pragmatically consistent with it. The "*we are too busy to improve…*" saying has less and less space in modern service-led and digitally-based manufacturing strategies.

6.3. Limitations and future research

Notwithstanding its novelty and relevance, the paper has some limitations that call for further investigations and refinements. First, an extension of the sampled cases would allow to find more robust evidence and improve the representativeness of the findings. The progressive acceleration of digital servitization projects in several manufacturing industries changes firms' positioning in the innovation journeys and rapidly changes the development scenario. This indicates that further repeated investigations will lead to larger and more significant samples and a more thorough validity, with a higher number of firms reaching the maturity phase of their initiatives. This way, we would be able to gain a deeper understanding of the digital servitization strategies viable by smaller B2B manufacturers than was found in our research.

In addition, our outcome variable could be analyzed more in-depth investigating the different impacts on configurations of further conditions: first, the effects of the specific learning through the interaction with KIBS as well as the problems that can hinder this learning (Grandinetti, 2018; Rapaccini et al., 2023); second, the specific type of activities that are internalized via new hirings and their complementarity with externally sourced ones; third, the role of the extant relationships of the firm's ecosystem (Tronvoll et al., 2020) – for instance, our cases testify that some of the established service providers are involved themselves in a transformation process that may well complement the manufacturers' one, in a mutual co-evolution (Kolagar et al., 2022b).

Finally, a further field of research is related to an overlooked aspect that will play a central role in the future, that is the upgrading of extant internal capabilities through training and requalification, to allow incumbent organizational structures to exploit their whole potential for business model innovation.

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CRediT authorship contribution statement

Christian Kowalkowski: Validation, Supervision, Conceptualization. **Roberto Grandinetti:** Writing – review & editing, Writing – original draft, Validation, Supervision, Conceptualization. **Mario Rapaccini:** Validation, Supervision, Conceptualization. **MARCO UGO PAIOLA:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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