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Value creation from combining digital and non-digital resources: The case of "smart products"

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ABSTRACT

This paper explores value creation from combinations of digital and non-digital resources in business networks. The theoretical lens used here is the Resource Interaction Approach, which relies on the Industrial Network Approach, which asserts that resource combinations across firm boundaries are key to value creation. Additionally, we identify unique characteristics of digital resources: transmissible, reproducible, and reprogrammable. The paper lays out an exploratory in-depth case study involving three actors and their relationships in a traditional manufacturing context. The case follows one of the actor's "smart products," which combines manufacturing equipment and software based on the Internet of Things and cloud technology; as such, these products build on combinations of digital and non-digital resources in their uses to create value. The paper provides the following typology of different resource combinations involving digital resources: diffusely transmitted, rapidly reproducible, and easily reprogrammable resource combinations. Resource combinations involving digital resources yield three forms of value creation: i) increasing data accessibility and knowledge creation; ii) increasing efficiency; and iii) promoting innovation throughout products' lifespans. The paper concludes by contextualizing the study's theoretical contributions and managerial implications, as well as proposing avenues for future research.

1. Introduction

Interest in how digital technologies can change the business landscape has grown among scholars and practitioners (Gnanasambandam et al., 2022; Verhoef et al., 2021), making firms' digital resources increasingly important (Hauke-Lopes et al., 2023; Henfridsson et al., 2014; Pagani & Pardo, 2017; Piccoli et al., 2022; Piccoli et al., 2024). This new focus is due to the growing role of digital resources (Piccoli et al., 2022)—such as data and information—in daily decisions, processes, and business interactions, driven by the vast amount of data that is generated (Marr, 2018). Business actors regularly use data to support their work, automate tasks, and create new business opportunities (Assur & Rowshankish, 2022), both within their firm and in collaboration with customers, suppliers, and other actors in their business networks (Pagani & Pardo, 2017; Ritter & Pedersen, 2020; Salo & Wendelin, 2013). Thus, studies have begun to highlight the significance of understanding the value created by digital resources in the business landscape (Corsaro & Anzivino, 2021; Eklinder-Frick et al., 2023; Ferreira & Lind, 2023; Hauke-Lopes et al., 2023; Ritter & Pedersen, 2020).

Digital resources are composed of bitstrings (Faulkner & Runde, 2019) with specific and unique characteristics (Piccoli et al., 2022; Piccoli et al., 2024). Piccoli et al. (2022, p. 2293) state that digital resources are generally regarded as "a specific class of digital objects that a) are modular, b) encapsulate objects of value, assets and/or capabilities, c) and are accessible by way of a programmatic interface." Consequently, and given this definition, digital resources can be reused and recombined in novel ways (Piccoli et al., 2024). However, it is primarily non-digital resources, such as physical or organizational resources, that have been extensively studied over recent decades (Baraldi et al., 2023; Barney, 2001; Dourado Freire et al., 2023; Elia et al., 2021; Håkansson & Waluszewski, 2002a; Helfat et al., 2023; Nason & Wiklund, 2018; Priem & Butler, 2001; Qiu et al., 2022; Sirmon et al., 2007; Vafeas & Hughes, 2020; Vargo & Lusch, 2008; Zhang & Wu, 2017), thus creating a growing need for studies examining digital

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resources, the combinations of digital and non-digital resources, and how they impact business networks.[1]

One theoretical perspective used to study resource combinations across firm boundaries is the Industrial Network Approach (INA) (Bocconcelli et al., 2018; Håkansson et al., 2009; Håkansson & Snehota, 1995; Håkansson & Waluszewski, 2002a; Holmen, 2001; Jahre et al., 2006; Landqvist, 2020; Lind, 2006). INA assumes resource heterogeneity (Penrose, 1959) and posits that the value of resources is not a given but rather depends on how a resource is combined with another resource; in this sense, a single resource has no value. Given that resources are heterogeneous, much attention has been paid to the interactions among various resources in business networks (Baraldi et al., 2012; Baraldi et al., 2023; Håkansson & Waluszewski, 2002a; Prenkert et al., 2022). Following the work of Hauke-Lopes et al. (2023), who argue that the two opposite categories of non-digital resources and digital resources "usually coexist and interact" (p. 1318), this paper aims to explore value creation by combining non-digital and digital resources in business networks.

The paper is outlined as follows. In the second chapter, we present an overview of digitalization and digital resource characteristics, as well as discuss current research on resource interactions and value creation; this culminates in a framework that combines non-digital and digital resources for value creation. Chapter three presents the case study research methodology, and chapter four presents the case. The findings from the case are analyzed and discussed in chapter five. The paper ends with chapter six, which lays out conclusions, emphasizes contributions and implications for both research and practice, and provides suggestions for further research.

2. Theoretical frame of reference

2.1. Digitalization and digital resources

The ongoing discussions on how digital technologies are used and implemented in organizations often divide the practice into three phases, illustrating how and the degree to which digital technology is implemented (Verhoef et al., 2021): digitization, digitalization, and digital transformation. Digitization refers to turning analog information into digital; digitalization is broader, and it describes an organization's increased use of digital technologies to alter and improve business processes (Ritter & Pedersen, 2020; Verhoef et al., 2021). Digital transformation, meanwhile, "describes a company-wide change that leads to the development of new business models" (Verhoef et al., 2021, p. 891) and that should drive new value (Pagani & Pardo, 2017). Examining digitalization and digital transformation through the lens of inter-organizational relationships is vital (Eklinder-Frick et al., 2023): different types of digitalization efforts have been identified in business networks, and they impact the actors, resources, and activities in different ways (Pagani & Pardo, 2017).

According to Hauke-Lopes et al. (2023, p. 1318), digital resources are "cheaper and easier to amplify, replicate and distribute" because of their digitized formats. In other words, digital resources are transmissible through distribution across contexts and devices and over information infrastructures (Kallinikos et al., 2013; Sandberg et al., 2020); this creates countless possibilities for new applications and uses thereof. Yet another aspect of digital resources outlined by Hauke-Lopes et al. (2023, p. 1318) is that they can be more "conveniently stored and retrieved, as well as accessed remotely." Additionally, Hauke-Lopes et al. (2023) also point out that digital resources can be easier to replicate—i.e., reproduce—compared to physical (non-digital) resources; hence, digital resources have a reproducibility aspect, in that anything encoded into a digital format can be reproduced (Benkler, 2006; Henfridsson et al., 2014). Finally, digital resources are editable (Piccoli et al., 2022): new features can be added to, e.g., smart products after initial product design, and new combinations of functions can be created through connectivity and reprogrammability (e.g., by using gateways and application programming interfaces (APIs)) (Henfridsson et al., 2018; Sandberg et al., 2020). Thus, by being reprogrammable, digital resources can expand a product's functionalities through programs and software changes.

2.2. Resource interaction approach

Within INA, a stream of research called the Resource Interaction Approach (RIA) has developed, focusing specifically on interactions among resources (Baraldi et al., 2012; Baraldi et al., 2023; Håkansson & Waluszewski, 2002a; Prenkert et al., 2022). Resources are developed in interaction when they are combined with other resources (Bocconcelli et al., 2020), and resource interaction in inter-organizational networks involves "the processes of combination, recombination, and co-development of resources that happen through the interaction among organizations" (Baraldi et al., 2012, p. 266). Resource combinations depend on the interfaces among resources. Specifically, the resource interaction model differentiates tangible (i.e., technical) resources and intangible (i.e., organizational) resources (Håkansson & Waluszewski, 2002a): technical resources refer to products and facilities, while organizational resources are social and immaterial resources found inside firms, such as skills, personnel, organizational structure, routines, or knowledge (Baraldi, 2003). The organizational resource of 'business relationships' refers to "the sediments resulting with time from the interaction between organizational units" (Baraldi, 2003, p. 8). Accordingly, interfaces have been characterized as technical, organizational, or mixed (Dubois & Araujo, 2006). When it comes to digital and non-digital resources, interfaces could take the form of information about a non-digital resource being handled by a digital facility (Hauke-Lopes et al., 2023), or business relationships driving the implementation of IT systems (Baraldi, 2003).

According to the assumption of resource heterogeneity (Penrose, 1959), resources have no given value (Håkansson & Snehota, 1995; Holmen, 2001): only when actors mobilize the resources do their features emerge, through interactions (Baraldi et al., 2012). Additionally, the concept of usefulness stresses that a resource must demonstrate an actual or potential use (Holmen, 2001) in relation to both producers and users (Håkansson & Snehota, 1995). For this reason, resources are "double-faced," and the producer of a resource can only partially shape its potential value, as the actual value is defined when the resource is used in a context (Baraldi et al., 2012). Resources are also regarded as open and variable, given that their values emerge from resource combinations, which involve interactions with other actors in networks (Prenkert et al., 2022); consequently, changing the resources with which a resource is combined alters that resource's value and promising features (Baraldi et al., 2012).

2.3. Value creation from resource interaction in business networks

The primary objective for a customer firm and a supplier firm establishing a collaborative relationship is to work together in ways that either add value or reduce costs through their exchanges (Anderson, 1995). In collaborations, the interaction between actors and resources is a determinant of finding solutions and, thus, of value creation (Håkansson et al., 2009). In interactions, value can be created for individual firms (actors) and/or span across firm boundaries, depending on how resources are combined and developed (Håkansson & Waluszewski,

[1] We take on the definition by Anderson et al. (1994. p. 2): "A business network can be defined as a set of two or more connected business relationships, in which each exchange relation is between business firms that are conceptualized as collective actors. […] Moreover, two connected relationships of interest themselves can be both directly and indirectly connected with other relationships that have some bearing on them, as part of a larger business network."

2002a; Lind et al., 2012). Value results from both the uniqueness of a specific resource and its combinations with multiple interconnected resources (Prenkert et al., 2022); hence, relationships that are developed with customers can influence, configure, and sustain the value-creation process (La Rocca & Snehota, 2014).

Defining the value of a resource is contextual and considers the specific combination of single resource features and how these specifically relate to other specific features when resources are used (Prenkert et al., 2022). Value can be considered as a trade-off between benefits and sacrifices (Walter et al., 2001) and may take different forms, such as knowledge, safety, or profits; it can be categorized as indirect or direct. Moreover, actors perceive value differently (Cantù et al., 2012), and due to the complexity of a business network, in most cases it is not always clear to all actors how to capture the value in the business network (Lind et al., 2012).

From a supplier point of view, value creation can be seen as the capability to address customer issues by developing and enhancing knowledge, which enables both supplier and customer to make better decisions and achieve innovation (Gadde & Snehota, 2019; Guenzi & Troilo, 2006). It can also arise from supply chain collaboration, which leads to efficiencies and cost savings across various business processes (Gadde & Snehota, 2019; Horvath, 2001). Accordingly, innovation and efficiency are forms of value creation that can emerge from resource combinations and collaborations.

Innovation has been considered to be a result of resource interactions and combinations (see, for example, Ingemansson (2010)). Interaction involves creating links between interdependent resources in a network context; to this end, innovation processes "need to be understood in terms of interaction and innovation outcomes as relational effects" (Hoholm & Araujo, 2017, p. 107). These processes can include more or less complex patterns, ranging from simple exchange to mutual adaptations between the actors involved (Håkansson et al., 2009). Thus, the business network structure has implications for the innovation process, due to resources becoming increasingly embedded into network actors' other resources and activities (Aarikka-Stenroos et al., 2017; La Rocca & Snehota, 2014). As such, and as stated by Aarikka-Stenroos et al. (2017, p. 89), "innovation involves creating interfaces between resources and understanding the differing logics of actors." In summary, the propelling forces of innovation are the outcomes of joint actions and interactions among actors in a business network (Hoholm & Araujo, 2017).

As mentioned earlier, joint actions and collaboration can also lead to efficiency gains in business processes. Efficiency can be achieved through the interlinking of activities, the creative use of resource heterogeneity, and mutuality based on actors' own interests (Anderson et al., 1994). At a certain point in time, resources that are controlled and used by actors may be regarded as a given; however, due to the dynamics inherent in this process, they interact, whereby new resources and resource combinations are developed over time (Dubois, 1998). Håkansson and Snehota (1995) point out that the purpose and scope of the use of a resource is not given, just as actors' identities, perceptions, and intentions are never entirely given. Resource utilization changes and develops gradually, and research shows how activities are reorganized among firms and how the conditions for resource utilization change (Dubois, 1998); efficiency results from such changes in resource use, and when interdependence between activities prevails, resource control is not needed for firms to be efficient.

2.4. Research framework and questions

This paper considers resources as either digital or non-digital (Hauke-Lopes et al., 2023). Digital resources are characterized by a bitstring format (Piccoli et al., 2022; Piccoli et al., 2024), and all other resources that are not bitstrings are regarded as non-digital resources; digital resources are unique with respect to their transmissibility, reproducibility, and reprogrammability. The paper also distinguishes non-digital resources as technical/tangible (e.g., computers and personnel) or organizational/intangible (e.g., knowledge), based on Håkansson and Waluszewski (2002a), to emphasize resource interaction. This approach creates resource interfaces between non-digital resources characterized as technical, organizational, or mixed (Dubois & Araujo, 2006) as well as interfaces between digital and non-digital resources (Hauke-Lopes et al., 2023). Here, resource interaction appears at the interfaces between digital and non-digital resources. The value of all resources, digital or non-digital, depends on how they are combined with other resources, and resource interaction is thus crucial for value creation. The logic is summarized in the research framework (see Fig. 1).

Drawing on the above, this study seeks to answer the following research questions (RQs):

1) How does resource interaction characterize digital and non-digital resource combinations?
2) How is value created from resource combinations involving digital and non-digital resources?

3. Research method

Given the explorative nature of the study, this paper adopts a qualitative explorative case study design and research methodology (Easton, 2010; Flick, 2014; Lindgreen et al., 2021) to capture the interplay between digital and non-digital resources (Hauke-Lopes et al., 2023) and the subsequent value creation of "smart products" (Raff et al., 2020) in a business network (Anderson et al., 1994). A single case method offers an opportunity to obtain detailed, in-depth, contextual knowledge of a specific and contemporary phenomenon (Dubois & Gadde, 2002; Flyvbjerg, 2006), such as digitalization (Galvani & Bocconcelli, 2022). This method has proven to be a fruitful approach in studies conducted in a business network context (Dubois & Gibbert, 2010; Easton, 2010; Halinen & Törnroos, 2005).

3.1. Case sampling and data collection

Alpha, the case firm in this study, was chosen because of its work in traditional manufacturing (non-digital), its use of Internet of Things (IoT) solutions (digital), and the intersection between the two. Alpha is part of the welding industry; it develops, produces, and sells "smart products", namely welding machines used by customers to weld metal parts in their production lines or workshops. Welding is the primary process of our empirical case, and the investigation centered around how digital and non-digital resources are combined to create value in the welding context.

Fifteen semi-structured interviews (Flick, 2014) were performed in 2020–2022 with Alpha's employees (13 interviews), its supplier Beta (1 interview), and its customer Gamma (1 interview). The sampling method followed a snowball method, meaning that one interviewee identified other relevant informants with knowledge of the issues under study (i.e., the interaction between non-digital and digital resources). Our informants in Alpha worked in various areas related to R&D, product management (PM), and various global management and directors' positions[2]: we interviewed R&D managers of digital solutions (2), PM of digital solutions (3), PM of digital documentation application (1), general manager of digital solutions (1), R&D managers of welding equipment (2), PM of automation (1), PM of solid wires (1), global welding equipment director (1), and global director of supplier development (1). Moreover, we interviewed the supplier and the customer once each—specifically, a technical specialist at Beta, and a pair interview with one process manager and one process worker at Gamma.

While the themes of the interview guide were adapted to fit each interviewee, the interview guide revolved around and focused on: (i) organizational unit and structure related to digital solutions and

[2] The numbers in parentheses relate to the number of interviews.

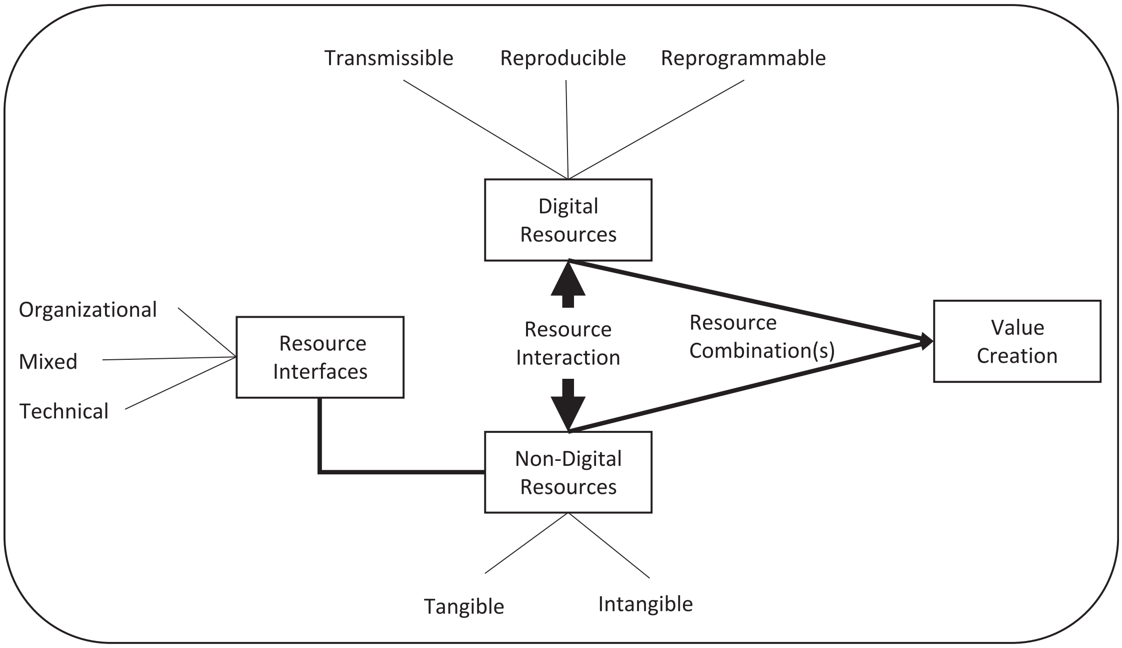

Fig. 1. Framework for analysis of resource combination of digital and non-digital resources.

connected machines; (ii) current business situation and plans; and (iii) external collaboration, supplier relationships, and customer relationships with respect to the "smart product." For Gamma, the interview focused on the context of the smart product and the Alpha–Gamma relationship, while for Beta, the main focus was the technical aspects of the solution. The average duration of the interviews was 54 min.

In addition to the interviews, data were collected from various secondary sources, such as technical documents and reports (PowerPoint presentations) provided by the interviewees, industry reports, case reports on user cases, and information from the actors' websites.

3.2. Data analysis

We applied an abductive logic to our research (Dubois & Gadde, 2002). This logic permits an interplay between theory and empirical fieldwork by confronting the theory with the empirical world. Following this logic, our coding process has been driven by the INA concepts, in that "alternating between the theoretical domains inspires the search for empirical data, and new data open up for adjustments in the theoretical domain" (Eriksson et al., 2022, p. 91). Other streams of literature connected to digital resources were additional sources of inspiration. Overall, the focus of this study was to develop and advance theory about a phenomenon (Zeithaml et al., 2020), which in our case is the phenomenon of combining digital and non-digital resources to create value. It is important to point out that even though new value can be created through combinations involving digital resources, Alpha's physical welding process is still the main process. This means that when discussing this type of "smart product," our study considers that the non-digital resources of the physical artifacts (e.g., welding machines and consumables) will always have importance, with no intention to replace the non-digital resources with the digital resources.

The case analysis of digital and non-digital resources relies on Alpha and two selected relationships: one with the customer (Gamma), and one with the supplier (Beta). Aspects of the specific resource combinations between Alpha and Gamma and between Alpha and Beta are included in the analysis of this case; however, these are mostly taken from Alpha's perspective on the relationships and the resource combinations of the non-digital and digital resources.

In summary, our case and its analysis were built by triangulation of data, which included interviews and secondary sources (Dubois & Gibbert, 2010; Flick, 2014; Lindgreen et al., 2021). The case study approach allowed us to capture the complexity of value creation by a focal firm, its supplier, and its customer, with a specific focus on resources and resource interaction; it also allowed us to add to existing theoretical frameworks (Eisenhardt & Graebner, 2007) and conceptualization (Dubois et al., 2023). Moreover, we view an understanding of digital and non-digital resources, as well as a typology of the resource combinations forming the foundation of value creation, as relevant beyond this specific context through analytical generalization (Dubois & Gibbert, 2010).

4. Case

First, this chapter describes the case in terms of the smart product producer Alpha, the IoT supplier Beta, the pilot customer Gamma, and the smart product solution. Second, it depicts how Gamma uses connected welding machines and digital solutions.

4.1. The case of the smart product

In this case, the smart product producer is Alpha, a manufacturer of welding and cutting equipment and consumables that are to be used on assembly lines as well as in workshops. Usage of the welding equipment and consumables by the customers is similar to that of a printer (equipment) and cartridges (consumables); hence, Alpha's goals are to sell the equipment and to maintain relationships with customers by supplying the consumables that are used in connection with the equipment.

Alpha has started to create "smart products" and now offers different software applications based on IoT and cloud technology. Alpha has been supported by IoT suppliers in the development and commercialization of these technologies. Beta, the IoT platform supplier, is one key supplier; it provides the IoT cloud platform infrastructure. This IoT platform consists of the first layer of the digital solution; on top of this infrastructure, Alpha develops and sells new software application modules. Beta is also responsible for storing Alpha's customer data in its cloud solution. Alpha is an important customer for Beta, since it is the first firm in the welding industry to do business with Beta; their business relationship is even stated on Beta's website as a story case.

Alpha started their sales of IoT offerings a few years ago, but the majority of the customers still do not connect their machines to the cloud. Among the first customers of the IoT offerings is Gamma, who is also a close partner of Alpha. Gamma performs the role of pilot customer, testing new software and giving feedback to Alpha regarding the applications. Gamma has been a customer of the documentation and fleet management software modules for a few years, and it is now testing the application productivity in its fleet of welding machines. See Fig. 2 for an illustration of the three actors.

The IoT offerings provided by Alpha include, among others, the following software modules sold as subscriptions: 1) productivity, which consists of a steady stream of real-time data that allows customers to identify specific areas for process improvement; 2) fleet management, which allows customers to trace the machine fleet and provide details on the machine status; and 3) documentation, which allows customers to automatically document and log data (e.g., work characteristics, consumables, and operators). A number of resources are involved in the business exchange between Alpha and Gamma. As an overview, Table 1 shows a list of digital resources (DR) and non-digital resources (NDR) that are interconnected in the smart product offering, paired with the actors who store and own each resource.

4.2. Data and IoT in connected welding machines

Data and IoT technology have become crucial in the welding solutions that Alpha sells. Alpha's employees have recognized that welding machines are now computers that can weld, rather than simple power sources, and Gamma has been using the different software modules provided by Alpha in its welding processes. For example, Gamma uses IoT technology when it accesses the fleet management module to track the status and health of connected welding machines. Gamma is one of the ten largest petrochemical companies in the world; accordingly, the industrial site where Gamma uses the fleet management module is very extensive, with several welding machines spread out across different locations and workshops; through the fleet management module and connected machines, Gamma's engineers can configure and control key system parameters for the welding machines at a distance using a computer or a mobile phone. Specifically, Gamma's welding engineers first define and configure the parameters of a welding machine for a specific welding process; then, they manually add the parameters in a welding machine for welding work, using a local computer connected to the welding machine. As soon as the parameters are tested and confirmed, they are distributed to the dozens of different welding machines spread across the site. Before the existence of the fleet management application and machines that can be connected, this work was done by walking around the site with a pen drive to plug into the welding machines' USB ports, taking up a significant amount of time. Thanks to the fleet management module—a software application developed and sold by Alpha—these parameters can be quickly reproduced and transmitted synchronously by Gamma's engineers to several connected welding machines.

The documentation module is another application that Alpha offers. Gamma appreciates this module, as managing welding documents and

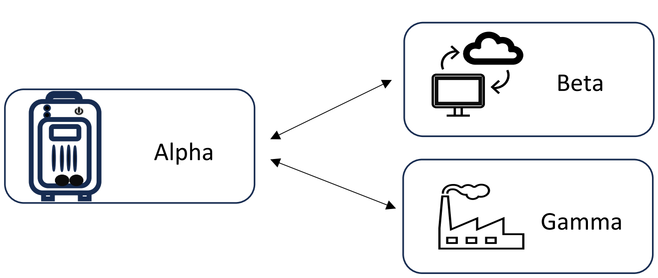

Fig. 2. Alpha, the smart product producer; Beta, the IoT platform provider; and Gamma, the smart product customer/user.

Table 1
Digital and non-digital resources in the smart product offered by Alpha.

Resource #	Resource description	Stored by	Owned by
DR1	Internal machine control software	Gamma	Gamma
DR2	Machine settings	Gamma	Gamma
DR3	Machine alarms and notifications	Gamma	Gamma
DR4	IoT gateway software	Gamma	Gamma
DR5	Reports resulting from the combination of cloud digital resources from the customer and the applications (Alpha)	Gamma	Gamma
DR6	Cloud storage – Machine settings	Beta	Gamma
DR7	Cloud storage – Machine alarms and notifications	Beta	Gamma
DR8	Cloud storage – IoT gateway software	Beta	Gamma
DR9	Cloud-stored – Reports that are combination of cloud digital resources from the customer and the applications from Alpha	Beta	Gamma
DR10	Welding applications – access through subscriptions	Beta	Alpha
DR11	Software that runs the cloud	Beta	Beta
NDR1	Welding machine	Gamma	Gamma
NDR2	IoT gateway component	Gamma	Gamma
NDR3	Customer personnel (e.g., welding engineer)	Gamma	Gamma
NDR4	Servers that create the cloud	Beta	Beta
NDR5	Technical support team	Beta	Beta
NDR6	Software developers	Alpha	Alpha
NDR7	Technical support team	Alpha	Alpha

reports is a critical activity for them. For example, when Gamma is required to send reports to a regulatory agency, which assesses Gamma's operations with regard to regulatory frameworks, the digital reports generated by the documentation module can present the information from the asked-for reports. In addition, Gamma's engineers and production managers use the data provided by the productivity module to follow up on critical welding processes in real time, thereby making it possible to quickly act and make decisions about the operation process if needed. Gamma also uses the productivity module to identify areas for welding process improvement and to validate the welding process in production, especially the quality aspects of the weld.

Whenever the connected machines at Gamma are online, they can receive software updates sent by Alpha through the internet. These updates may entail either bug fixes for existing issues or the introduction of new features created to improve the welding process.

5. Analysis

In chapter two, we posed two research questions: (1) How does resource interaction characterize digital and non-digital resource combinations? and (2) How is value created from resource combinations involving digital and non-digital resources? In this chapter, these two research questions are answered, and the research findings are discussed.

5.1. Identifying digital and non-digital resources

When Alpha's smart product offering is used at the customer Gamma to generate a monitoring digital report, several resource interfaces and interdependencies in this context are revealed. The digital and non-digital resources, as well as the resource interfaces that are activated when the connected welding machine are in use at Gamma, are presented in Fig. 3 (the digital and non-digital resources are the same ones as those listed in Table 1). Considering the storage place and the resource ownership makes evident the role of the supplier Beta in storing digital resources in the cloud from other actors; in this case, Beta stores data from Alpha and Gamma, creating a certain level of interdependence among these actors.

The digital reports in DR5 and DR9 are digital resources created from a combination of both digital and non-digital resources: a non-digital

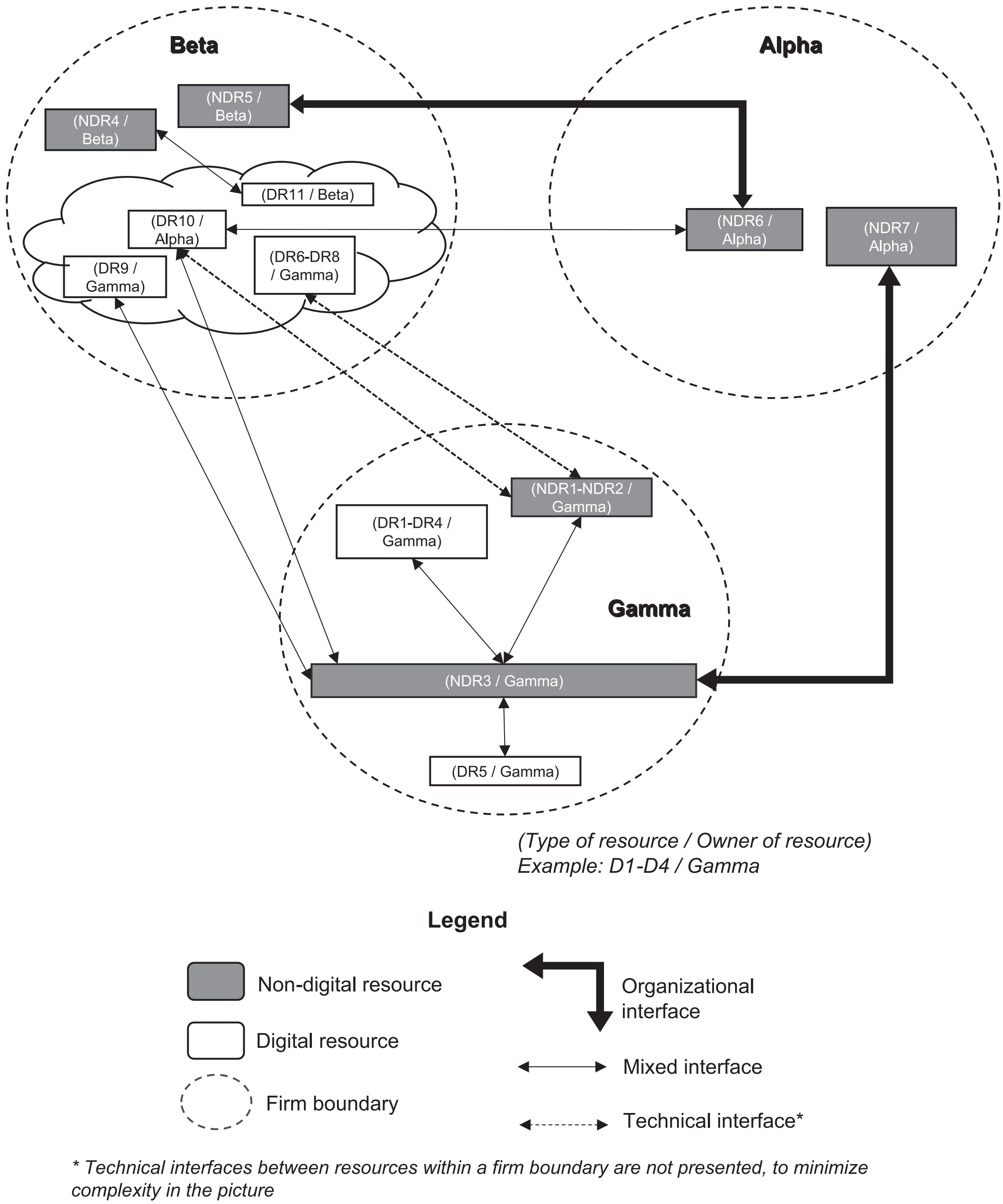

Fig. 3. Digital and non-digital resources in the use of the smart product offering and the respective interfaces.

resource, "welding machines" (NDR1), is combined with a digital resource, "welding software applications" (DR10), to create the digital reports. In order to implement this combination, parameters related to the welding machines (non-digital resource)—e.g., values of the electrical current during the welding process—are captured by sensors in the machines and converted into digital data (digital resource). These digital data (digital resource) from Alpha's customers are combined with the digital resource "welding software applications" (DR10), which is owned by Alpha but accessed by Gamma through subscriptions.

Gamma and Beta are constantly connected through technical interfaces. Additionally, mixed interfaces between Gamma and Beta are activated when Gamma engineers access the digital reports. Finally, organizational interfaces between Gamma and Alpha need to be activated when more complex applications are offered by Alpha or when issues emerge with the smart product at Gamma. Organizational interfaces are necessary, and interaction between humans occurs when complex problems are hindering the smart product from functioning properly.

The essential role of humans, specifically software and welding engineers, is identified in this case as ensuring the performance and evolution of "smart products" over time. The interactions between engineers from Alpha and Gamma working to resolve issues or implement new features form the organizational interfaces are crucial for the business. These interactions transform the dynamics of the interfaces: instead of only exchanges of bitstreams between systems, engineers share ideas, knowledge, and occasionally materials, such as new hardware components. Over time, these intermittent interactions across organizational boundaries have been refined and optimized through mutual learning on managing “smart products”, leading to mutual benefits. Respondents from Gamma even noted that such learning has significantly improved the exchange of ideas when addressing problems associated with newly implemented features.

Interdependencies among these three actors are observed when the smart product is used to create and monitor digital reports: Gamma is the actor performing the welding process and accessing the digital reports generated by the software; Alpha, who developed the software, is providing access to the software; and Beta is responsible for the data storage and the infrastructure underpinning the IoT platform. The fact that some actors own data that is stored by other actors brings even more interdependencies.

5.2. Types of combinations involving digital and non-digital resources

The above analysis shows how “smart products” require resource combinations of both digital (e.g., DR4, DR10) and non-digital resources (e.g., NDR4). These resource combinations cut across the firm boundaries of Alpha, Gamma, and Beta, and the resource ownership and storage vary among the actors, creating interdependencies. Hence, it is possible to gain an understanding of how the characteristics of digital resources are related to resource combinations (Prenkert et al., 2022) in the context of “smart products” (Pardo et al., 2022).

For analytical purposes, different aspects and uses of the smart product offering were selected, from the empirical case, and analyzed separately in order to best illustrate the characteristics of the resource combinations. However, it is important to note that all the aspects and uses regard the same smart product offering provided by Alpha, that in reality these can occur simultaneously, and that many other types of uses of the smart product also exist. That said, from the case, we identify three different types of resource combinations involving digital and non-digital resources: diffusely transmitted resource combinations, rapidly reproducible resource combinations, and easily reprogrammable resource combinations. All resource combinations may lead to value creation, which is discussed in section 5.3.

The diffusely transmitted resource combination is characterized by the fact that digital resources can be diffusely transmitted. The productivity module, a software application developed and sold by Alpha and accessed by Gamma through a subscription, formed the basis for identification of this type of resource combination. Computers and mobile phones can leverage real-time connections to the welding machines to receive performance reports (digital resource) about the welding processes, which are stored by Beta in the cloud. Thanks to the fact that digital resources can be transmitted, it is possible to have any ideal (short or long) distance between a focal digital resource (in this case, performance reports about the welding process) and the other digital and non-digital resources in the combination. Moreover, a wide variety of non-digital resources (such as mobile phones and screens) can be combined to access and visualize the focal digital resource.

The second type is the rapidly reproducible resource combination. This type of resource combination is characterized by the reproducibility aspect of digital resources: because digital resources are reproducible, usually only a short time is required to combine resources so as to create a reproduced digital resource (i.e., new copies of the original digital resource). The fleet management module, used by Gamma to distribute welding-machine parameters to different machines at the same time, was the basis for identification of this type of resource combination. Welding engineers can create new welding parameters (digital resources), seamlessly reproduce them, and transmit them through the internet to machines (non-digital resources) in different locations. Lower marginal costs are observed for resource combinations involving reproduction of digital resources, compared to the reproduction of tangible resources.

The third type of resource combination is the easily reprogrammable resource combination. The basis for the identification of this resource combination type was the fact that whenever Gamma’s connected machines are online, they can receive software updates sent by Alpha through the internet. This type of resource combination is characterized by the reprogrammability aspect of digital resources in combinations; an easily reprogrammable digital resource can be modified and developed when, in the process of resource combination, it can be reprogrammed by other resources. This ease leads to numerous opportunities to create new resource combinations over time, such as combining a particular resource with other new digital resources (e.g., programs or updates).

These types of resource combinations align with the characteristics of digital resources described in section 2.1, namely transmissibility, reproducibility, and programmability. Each of these combinations involves at least one digital resource, and one of the characteristics is activated when the resource is combined with other resources, whether digital or non-digital. It is important to note that even when the relevant characteristic(s) of the digital resource(s) is activated, value is created only when the digital resource is part of a combination.

It is important to recognize that these three types of resource combinations involving digital resources are interwoven and can occur simultaneously. For example, in the context of “smart products”, a reproduced resource resulting from a rapidly reproducible resource combination can be transmitted to another location via a diffusely transmitted resource combination to be combined with other non-digital resources. The provided typology with its three types of resource combinations aims to facilitate comprehension of the different characteristics of digital resources and how each one impacts resource combination.

Other studies have investigated how digital technology impacts companies’ ways of interacting and doing business (Fremont, 2021; Salo & Wendelin, 2013). For example, Pagani and Pardo (2017) provide a typology that classifies digitalization based on the modification of interactions between actors, to emphasize the role played by digitalization in the transformation of business networks. Our study builds on Pagani and Pardo (2017) by focusing on the resource dimension of business relationships. Through its analysis of the characteristics of digital resources (which gain meaning when they are combined with other resources), this study conceptualizes resource combinations that involve digital and non-digital resources.

5.3. Value creation from combining digital and non-digital resources

Value can take different forms and be perceived differently by different actors (Cantù et al., 2012); furthermore, value can be created for individual actors and/or traverse firm boundaries (Lind et al., 2012; Håkansson & Waluszewski, 2002ab). Drawing on the above analysis of resource combinations involving digital resources and the specific characteristics of digital resources, we identified three different forms of value from combining resources in “smart products” (see Table 2): i) increasing data accessibility and knowledge creation, through diffusely transmitted resource combinations; ii) increasing efficiency, through rapidly reproducible resource combinations; and iii) promoting innovation throughout the product lifespan, through easily reprogrammable resource combinations.

As shown in Table 2, value can be created for different actors in the business network, depending on the context and whether the value is co-created (Forsström, 2005; Hauke-Lopes et al., 2023). The following subsections provide a detailed account of how value is created and identify the beneficiaries of each type of value creation.

5.3.1. Increasing data accessibility and knowledge creation through diffusely transmitted resource combinations

Digital and non-digital resources in “smart products” can increase data accessibility and knowledge creation through diffusely transmitted resource combinations. This is due to the fact that digital resources can easily be transmitted to different locations and accessed by a variety of digital devices. The diffuse transmission of digital resources through network infrastructures (for instance, the internet) creates easy and

Table 2
Digital resource characteristics, types of resource combinations, and value creation forms.

Digital resource characteristic	Typology of resource combination involving digital resources	Value creation forms	Value for whom in the business network
Digital resources are transmissible	Diffusely transmitted resource combinations	Increasing data accessibility and knowledge creation	Direct value for smart product user Indirect value for the smart product producer and IoT infrastructure supplier
Digital resources are reproducible	Rapidly reproducible resource combinations	Increasing efficiency in the process of distributing data	Direct and co-created value for smart product user and producer Indirect value for the smart-product producer and IoT infrastructure supplier
Digital resources are reprogrammable	Easily reprogrammable resource combinations	Promoting innovation throughout "smart products'" lifespan	Direct value for smart product user and producer Indirect value for IoT infrastructure supplier

flexible access to data (digital resource); when these data (digital resource) are interpreted, whereby meaning is given to them, inter-organizational knowledge is created and complexity is simultaneously increased through the interaction between humans and technology (Plangger et al., 2020). The created inter-organizational knowledge is often the result of digital and non-digital resource combinations from different actors. In this case, inter-organizational knowledge is a result of the interpretation of the digital reports, which themselves are a result of the templates and measurements designed by Alpha and the data from the welding process performed by Gamma.

In this case, digital monitoring reports are created through resource combinations involving Alpha and Gamma and are stored in the cloud (by Beta). The cloud enables Gamma to access these reports from anywhere with internet access using a mobile phone or computer and thereby creates value. The mixed interfaces in these resource combinations are crucial for value creation, as exemplified by the interaction between a welding engineer (non-digital resource) and the digital reports (digital resource) generated by software applications (digital resource). It is the welding engineer at Gamma who reads, interprets, and utilizes the information from these digital reports, whereby value is created for the smart product user; hence, the human aspect is crucial in this mixed interface. The value manifests in enhanced knowledge about the welding processes, including machine productivity and fleet status; this knowledge leads to more informed decisions regarding improvements and management of the welding processes, underscoring the importance of mixed interfaces and the human aspect in the value-creation process.

As Henfridsson et al. (2018) state, digital resources are the building blocks for creating value from information, making easy access to information and knowledge valuable. This type of resource combination shows how mixed interfaces are essential for value creation, and the interaction between humans (in this case, welding engineers) and the IoT technology can even require new skills for humans (non-digital resource) to be able to deal properly with the digital resources involved.

While the above clearly demonstrates how direct value (Lind et al., 2012) is created for the user of the smart product—i.e., in the form of easy access to information and knowledge—it is important to note that diffusely transmitted resource combinations also create value for the smart product producer (in this case, Alpha) and for the IoT platform supplier (Beta), albeit in an indirect way. Digital resources increase data accessibility for both the producer and the IoT platform supplier, whereby Beta and Alpha can read and interpret Gamma's data (digital resource) to increase their knowledge about usage patterns for how Gamma actually uses the welding machines. (For Alpha, the data they access is in the form of compiled digital reports, due to the general data protection regulation.)

The interviews with Alpha revealed that Alpha actively uses this data (digital resource) to learn about how its customers are actually using the machines (non-digital resource); furthermore, the interviewees mentioned initiatives to make use of this new knowledge as inputs for research and development. Hence, the value created for Alpha is an indirect value. However, Alpha has been careful in its treatment of this knowledge, since few machines are connected to the internet, meaning the representativeness is still low. For its part, by accessing "customer data" (digital resource), Beta is learning about the welding industry in broad terms, which increases its capabilities and reputation in the eyes of other potential clients from the welding industry. The value (Lind et al., 2012) created for Beta was identified as an indirect, "nice to have" value, since it was not as important for Beta (the IoT platform supplier) as it was for Alpha (the producer).

However, it is not guaranteed that the easy access of digital resources (e.g., data) will create value for the actors involved. Digital resources can be easily transmitted to create new combinations, which opens up numerous new possibilities for resource combinations; this can bring confusion, since too many possibilities are not always positive and can cause information overload (Benselin & Ragsdell, 2016).

5.3.2. Increasing efficiency through rapidly reproducible resource combinations

In the case presented in this study, it was observed that efficiency can be increased through rapidly reproducible resource combinations. As explained in earlier sections, a digital resource is formed by bitstrings, which is a unique characteristic that enables digital resources to be easily and quickly reproduced, transmitted, and accessed through digital devices. The use of the fleet management application is a good example of how value is created when digital resources are rapidly reproduced, combined, and sent to other machines (non-digital resources).

The value created by this resource combination comes in the form of an economy of scale and saving time for Gamma, the smart product user. Gamma operates large sites where its "smart products" are typically dispersed across different areas; as a result, Gamma places greater importance on and experiences more value creation from rapidly reproducible resource combinations. This is in line Baraldi et al. (2012), who state that it is other actors in the network who shape the features and even economic value of resources. For users such as Gamma, rapidly reproducible resource combinations create value in terms of the efficiency in their processes of distributing data or information.

In this example, direct value is created for Gamma in the form of increased efficiency. Moreover, indirect value connected to this resource combination is observed for Alpha and Beta as they can gain new customers when they present the Gamma business case to existing and potential customers: the efficiency created from these resource combinations may attract customers, who could choose to engage with Alpha and/or Beta to enhance their processes.

5.3.3. Promoting innovation throughout product lifespan through easily reprogrammable resource combinations

As explained above, reprogrammability involves the ability of the connected welding machines to receive new updates (in the form of sets of logic) to modify their behaviors and functionalities. This process can increase the speed and the ways in which the connected welding machines owned by Gamma can be reprogrammed, changed, and even redesigned: because the connected machines—themselves combinations of digital and non-digital resources—can connect to the internet, new functionalities can be incorporated at any time, even after the machines have started welding operations at Gamma's site.

The numerous opportunities for new resource combinations and the arrival of new updates over time create value for Gamma, the smart product user, in terms of fostering innovation throughout the lifespan of the connected welding machine. The importance of a mixed interface becomes evident as the connected welding machine (a non-digital resource) continues to gain new and innovative features: these features are made possible through the combination of new digital resources with existing ones, facilitated by the dynamic and evolving nature of the mixed interface consisting of Alpha's software engineers and Gamma's connected machines. In this way, mixed interfaces are not just technical constructs but also involve human interactions, as engineers and users play a critical role in leveraging the exchange to combine new digital resources with existing (non-digital) ones. This human element enhances the effectiveness of mixed interfaces, enabling the connected welding machine to continually evolve and gain innovative features. Thus, the collaborative efforts of engineers working with the machines and creating mixed interfaces are essential to achieving ongoing innovation and value creation.

The value creation from easily reprogrammable resource combinations, in the form of innovation, is understood as a direct value (Lind et al., 2012) created for the smart product users. However, it is important to note that these types of combinations also create direct value for smart product producers. In this case, innovation results from the producer's efforts to create new digital resources, such as software updates and new software, most of which are conducted jointly by the smart product producer and user. The latter performs the role of pilot customer, usually suggesting new desired features to the producers and testing the new software developed by the producers. In this way, the smart product producer continually works on innovation and aims to reprogram digital resources in new resource combinations. For the IoT platform supplier (Beta), indirect key value is created, as new resource combinations require them to develop and provide the proper infrastructure and digital components to support the innovative joint initiatives over time. Consequently, an IoT platform supplier that can support new requirements will reinforce its network position and continue to be an important actor in a business network involving "smart products."

6. Conclusions and implications

6.1. Theoretical contributions

Understanding how to concurrently manage non-digital and digital resources is an important challenge in industrial markets as firms develop their business models in the context of digitalization and digital transformation (Eklinder-Frick et al., 2023; Gnanasambandam et al., 2022; Hauke-Lopes et al., 2023; Piccoli et al., 2024; Verhoef et al., 2021). By taking resource interaction as its starting point (Bocconcelli et al., 2020; Prenkert et al., 2022), our study adds to this discussion by examining and providing an understanding of the resource combinations of digital and non-digital resources, their interfaces, and the identification of distinct forms of value creation in business networks.

In their study, Pagani and Pardo (2017) relate digital transformation to certain value creation logics by identifying one type of value creation for each type of digitalization, which in turn are related to each dimension of the Actor-Resource-Activity (ARA) model (Håkansson et al., 2009; Håkansson & Snehota, 1995). Our study contributes to and expands the current literature on what digitalization in business networks entails (Pagani & Pardo, 2017), especially in the resource dimension (Baraldi et al., 2023; Håkansson et al., 2009; Håkansson & Snehota, 1995); by doing so, it answers the call for more research on "the impact of digitalization on business relationships" from Ritter and Pedersen (2020, p. 188).

Specifically, this paper identifies three types of resource combinations: (1) diffusely transmitted resource combinations, (2) rapidly reproducible resource combinations, and (3) easily reprogrammable resource combinations. Building on Hauke-Lopes et al. (2023) in terms of analyzing digital and non-digital resources, this concept of the three types of resource combinations adds to the understanding of resource combinations involving digital resources. Moreover, this typology contributes to the RIA (Bocconcelli et al., 2020; Prenkert et al., 2022) by providing new nuances of the features of resource combination in business networks (Bocconcelli et al., 2018; Håkansson & Waluszewski, 2002a; Holmen, 2001; Jahre et al., 2006).

In addition, this paper provides an account of the respective value creation forms of these resource combinations, namely increased data accessibility and knowledge creation, increased efficiency, and the promotion of innovation throughout the "smart product's" lifespan. This furthers the understanding of the value created by digital resources (Piccoli et al., 2022; Piccoli et al., 2024) in combination with non-digital resources in business networks (Corsaro & Anzivino, 2021; Eklinder-Frick et al., 2023; Hauke-Lopes et al., 2023). By showing how resource interaction is linked to value creation in business networks, our findings answer the call for further research from Prenkert et al. (2022).

We also contribute to the discussion of digital transformation and how heterogeneous digital resources increasingly possess what Piccoli et al. (2024) call 'strategic primacy' through our focus on the criticality of interaction with external partners (i.e., other actors in the business network) for achieving organizational development, performance gains, and value for both customers and suppliers. In this way, the paper also contributes to the discussion of value in terms of for whom in the business network the value is created (Cantù et al., 2012; Håkansson & Snehota, 1995; Lind et al., 2012). This paper shows that value is created as a result of resource interactions and combinations (Håkansson & Waluszewski, 2002b; Lind et al., 2012). While Henfridsson et al. (2018) state that digital resources are the building blocks for creating value from information, our study shows that value can only be created when the digital resources are combined with other resources in a context. In other words, value creation is context- and application-dependent, and this study identified direct and indirect value created for different actors in the network by the various resource combinations.

6.2. Managerial implications

This paper provides practical implications for managers working in industrial firms involved in selling, buying, and/or using "smart products" in the context of digital transformation (Gnanasambandam et al., 2022; Verhoef et al., 2021). The first managerial implication from our study suggests that introducing "smart products" to a portfolio is a complex task for users and producers alike, requiring a wide variety of digital and non-digital resources (Hauke-Lopes et al., 2023), especially for the so-called 'old stalwarts' of traditional industries. For managers in companies acting as producers and users, such a task will make high demands of the personnel involved, as the employees will need to learn new skills and create new resource interfaces within and across the firm's boundaries in order to work with new digital and non-digital resources in different combinations.

For producers, changes in the structure of smart product offerings are expected to be frequent, especially given the reprogrammability aspect of digital resources. Therefore, producers need to be prepared to continuously create new programs and updates for the smart products, while users need to be aware that the smart product that they buy today will regularly change features. In addition, because digital resources are open and can be easily transmitted to create new combinations, they open up countless possibilities for an organization; this will bring opportunities, but it could also lead to confusion, since too many possibilities is not always a positive thing. Relatedly, having a strategy in place that supports decision-making regarding which possibilities to implement and which not is another managerial implication.

In light of the direct and indirect value created from combinations of digital and non-digital resources in "smart products", companies need to pay attention to value creation beyond their own business; this could involve users of "smart products", providers of platforms, and producers, all of whom need to be aware of direct and indirect value in the business network. An implication for the users of smart products is to pay attention to whom, outside their own organization, the created value will benefit, and if or how that value can be captured.

6.3. Limitations and future research

The concepts of resource combinations and value creation can only be understood and explored in a specific context; therefore, this study applied a case study method. Consequently, it has limitations related to specific and contextualized findings. Because the case is limited to the context of smart products and the use of IoT, opportunities for new studies in different contexts—such as other applications and digital technologies—are available for future studies. We expect that exploring resource combinations involving digital resources in the context of artificial intelligence (AI) would be an interesting topic for studies about resource combinations, value creation, and digital resources. It is highly likely that value creation in business networks relies on combinations of digital and non-digital resources, so learning more about the specific features of such combinations may be necessary to understand how to avoid value destruction (Hauke-Lopes et al., 2023).

In addition, exploring the role of humans in mixed resource interfaces is an interesting area for future research. For the firms Gamma and Beta in this case study, technical and mixed interfaces facilitate digital interactions, while organizational interfaces involving humans are essential when complex issues arise or advanced applications are needed. Such human-mediated interactions involving digital resources were identified as crucial for the value-creation process, making this an important area for further study. Furthermore, investigating how resource deficiencies (Tunisini et al., 2023) are managed in the context of digital and non-digital resource combinations presents an intriguing area for future research.

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CRediT authorship contribution statement

Carla Cleri Ferreira: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Frida Lind:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **Ann-Charlott Pedersen:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – review & editing. **Victor Eriksson:** Conceptualization, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Writing – review & editing.

Data availability

Data will be made available on request.

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