Resilience, complexity and digital transformation: three case studies in the valves industry

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Abstract

Purpose – This paper shows how the interplay between organisational resilience and environmental complexity justifies the existence of differentiated yet successful approaches to digital transformation.
Design/methodology/approach – A multi-case method is applied to test our research hypotheses by contrasting the digital transformation of three Italian companies in the valves industry.
Findings – Different combinations of technological and organisational tools, hence diversified digital transformations, can be successful, provided that they are supported by a coherent set of resilience factors and allow for the implementation of strategic approaches aligned with the resilience capacity of the firm.
Practical implications – Awareness that resilience capacity shapes digital transformation and the strategies available to engage with external complexity should focus managers to invest in the alignment and the reinforcement of the factors underlying organisational resilience.
Originality/value – Most literature so far focused on the antecedents to digital transformation. In contrast, this paper focuses on the transformation process and highlights how the resilience capacity of the firm affects the unfolding of digital transformation and the emergence of diversified yet successful paths. In addition, in contrast with a dichotomous approach to external complexity this paper shows that digital transformation involves a mix of complexity reduction and complexity absorption strategies.

Keywords Digital transformation, Resilience, Complexity, Organisation change, Case studies
Paper type Research paper

1. Introduction

Digital technologies are probably the most pervasive innovation of the last decades and there is widespread agreement on their importance for firm competitiveness and innovativeness (Brynjolfsson *et al.*, 2018). However, adopting new technologies is not enough to achieve the intended business outcomes. Embedding digital technologies takes time and depends on organisation design, routines, capabilities and culture (Li, 2020). This process, which has been named digital transformation, "employs a combination of advanced digital technologies [. . .] and organizational practices [. . .] to enable major business improvements" (Imran *et al.*, 2021, p. 452).

If consensus on which indicators best measure success in digital transformation is still missing (Barthel, 2021), general agreement exists on potential support to company performance by means of renovated labour and information flows (Li, 2020). Effective integration of adopted innovations in organisation processes and a positive impact on company value and

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performance can thus be regarded as proxies for success in digital transformation. However, failure rates are high (Gale and Aarons, 2018). Research has therefore concentrated efforts on identifying the drivers of positive outcomes (Demeter *et al.*, 2021; Cimini *et al.*, 2021; Savastano *et al.*, 2022; Khin and Kee, 2022). From an initial focus on the assessment of technology-centred "maturity models" or "stage models" attention has progressively shifted to more holistic approaches that encompass firm strategy, organisation design and stakeholders' role (Imran *et al.*, 2021). Nevertheless, "the micro-mechanisms of the transformation remain hidden" (Demeter *et al.*, 2021, p. 821), while available evidence suggests that also in successful cases adoption timing and mode, usage patterns, organisation change and impact on firm performance widely vary across firms (Kiel *et al.*, 2017; Frank *et al.*, 2019; Bosman *et al.*, 2020; Codara and Sgobbi, 2020; Götz and Jankowska, 2020; Chen *et al.*, 2021; Nayernia *et al.*, 2021).

What justifies those differences? The literature has so far paid little attention to this question, also because of the fast pace of evolution and the uneven diffusion across industries and geographical areas (Ghobakhloo *et al.*, 2021).

This paper resorts to the construct of organisational resilience to justify the existence of diversified yet successful paths to digital transformation. Defined as "the capacity of a [. . .] system to absorb and adapt in order to sustain an acceptable level of function, structure, and identity under stress" (Dahlberg, 2015, p. 545), organisational resilience is an enabling factor of survival and success in a turbulent environment. Based on a strong set of shared values, the resilient organisation develops a vision of the competitive environment, devises a set of suitable goals and enacts appropriate routines to achieve those goals (Lengnick-Hall *et al.*, 2011). Resilience is therefore a powerful asset to navigate the complex external environment marked by dynamic and unpredictable relationships among diverse players and forces (Ashmos *et al.*, 2000) that typically accompanies digital transformation (Frank *et al.*, 2019; Li, 2020).

Based on key suggestions from the literature on organisational resilience and complexity we assume that different combinations of technological and organisational factors, hence differences in digital transformation, may prove successful, provided that they are supported by a coherent set of resilience factors and are meant to implement strategic approaches aligned with the resilience capacity of the firm. A multi-case method is applied to assess our research hypotheses by contrasting the digital transformation journey of three Italian companies in the valves industry.

The rest of the paper is organised as follows. Section 2 justifies the choice of resilience as the theoretical lens for explaining variety in digital transformation and details our research hypotheses. Section 3 introduces the empirical methodology that drove the development of the case studies reported in Section 4. Section 5 discusses the research findings and Section 6 draws some concluding remarks.

2. Resilience and digital transformation

2.1 Literature background

The literature has privileged theoretical frameworks that explicitly account for the interplay between technological and organisational components to explain the determinants and outcomes of digital transformation, with particular attention to the socio-technical approach (Cagliano *et al.*, 2019; Cimini *et al.*, 2021; Savastano *et al.*, 2022) and the theory of dynamic capabilities (Demeter *et al.*, 2021; Matarazzo *et al.*, 2021; Ellström *et al.*, 2022; Ghosh *et al.*, 2022). The application of those frameworks to the digital transformation poses nevertheless some important problems.

The socio-technical approach assumes that social and technical elements work together to accomplish organisational goals so that "change in one part of organisation triggers the need for change in other interconnected parts to ensure joint optimisation" (Imran *et al.*, 2021, p. 470). However, by assuming that digital transformation starts with the implementation of new digital technologies, focus on social opportunities and constraints associated with these

investments (Cagliano *et al.*, 2019; Imran *et al.*, 2021) implicitly subordinates the organisational dimension to the technological one.

The theory of dynamic capabilities adopts a reverse approach by placing more emphasis on the organisational dimension, or at least on organisational capabilities. Defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece *et al.*, 1997, p. 516) dynamic capabilities aim at explaining how companies can renew their competitive strategies in increasingly uncertain and complex environments. Accordingly, dynamic capabilities have been used to understand the organisational conditions that support the adoption of digital technologies in response to rapid market change (Warner and Wäger, 2019; Matarazzo *et al.*, 2021). However, this approach has been criticised due to ambiguous or even contradictory definition of key-concepts (Peteraf *et al.*, 2013) and non-robust empirical foundations that limit consistent measurement and constraint explanatory scope (Wang and Ahmed, 2007; Arend and Bromiley, 2009).

A more promising approach for our investigation into the origins of the variety of digital transformation is the concept of resilience (Conz and Magnani, 2020). In social studies resilience initially identified individual or system ability to recover from an adverse event and return to the previous level of functioning (Carver, 1998). The concept subsequently extended to thriving under frequent, eventually continuous and unpredictable change (Dahlberg, 2015) and in this sense has been widely used in business and management research (Linnenluecke, 2017).

Resilience enables firms to move beyond survival and actually prosper in complicated, uncertain and threatening environments. Accordingly, the exam of resilience may shed new light on differentiated paths to digital transformation, which takes place under complex and not completely forecastable conditions and may involve unexpected needs, opportunities and outcomes. However, the empirical measure of organisational resilience has proven challenging, often resulting in long, sometimes contrasting lists of attributes (Duchek, 2014; Dahlberg, 2015; Williams *et al.*, 2017).

Thanks to simplicity and a holistic approach to organisational dimensions, we adopt the framework proposed by Lengnick-Hall and Beck (2005) and Lengnick-Hall *et al.* (2011). According to Lengnick-Hall and Beck, a firm's capacity for developing resilience – *i.e.* resilience capacity – is achieved through cognitive factors (an organisation's ability to interpret unfamiliar situations), behavioural factors (ability to devise new ways of confronting these events) and contextual factors (ability to mobilize people, resources and processes to transform these choices into reality). Accordingly, resilience capacity is a unique blend of cognitive, behavioural and contextual properties that increases a firm's ability to understand its current situation and develop tailored reactive and proactive actions.

2.2 Resilience factors and digital transformation

Each basic resilience factor in the model initially developed by Lengnick-Hall and Beck (2005) further decomposes in two additional components. The cognitive dimension of resilience capacity originates from a combination of organisational identity and constructive sensemaking. Whereas organisational identity founds "on a strong sense of purpose, core values, a genuine vision, and a deliberate use of language" (Lengnick-Hall *et al.*, 2011, p. 245), constructive sensemaking "relies on the language of the organization (*i.e.* its words, images, and stories) to construct meaning, describe situations, and implies both understanding and emotion" (Lengnick-Hall *et al.*, 2011, p. 246).

The behavioural factor of organisational resilience, which turns cognitive properties into visible actions, results from two components: the inventory of operational routines, which govern day-by-day operations, and functional habits, which consist of the generative meta-routines (Adler *et al.*, 1999) that create and modify operational routines. By including both current routines and the procedures to change current routines among behavioural factors

Lengnick-Hall and Beck's model therefore accounts for both the knowledge exploiting and the knowledge exploring mechanisms that take place within an organisation (March, 1991; Boisot and Child, 1999).

The third factor of resilience capacity, contextual resilience, includes a firm's social capital and its resource network. Contextual resilience integrates cognitive and behavioural resilience by setting the framework of human and organisational relationships and competences where a company values and routines come into action (Polyviou *et al.*, 2020).

Lengnick-Hall and Beck stress that the overall resilience capacity is more than the sum of its factors and components, which interact according to non-linear and non-strictly predictable patterns. In addition, excellence in a single dimension is not enough to achieve a high level of resilience capacity, which rather increases with the coherent growth of all its underlying factors. All cognitive, behavioural and contextual factors concur in defining the space of viable strategies and actions and in shaping the actual form that they will take.

An understanding of resilience capacity and resilience factors provides key insights to explain why successful digital transformations characterised by different combinations of technological and organisational tools can be observed in the real world.

Past literature on the digital transformation has identified significant firm-level drivers in organisational variables such as leadership, culture, organisation structure, human resources and relationship networks (Cotta and Salvador, 2020; Imran *et al.*, 2021; Nayernia *et al.*, 2021). Under the lens of resilience, a unified lecture of those drivers becomes possible by recognising that they all connect with resilience factors. In addition, the acknowledgement that digital transformation drivers interact in non-linear and firm-specific ways (Frank *et al.*, 2019; Li, 2020) mirrors Lengnick-Hall and Beck's intuition of resilience capacity as a complex bundle of intertwined factors.

Variation in the resilience capacity of organisations will result in the adoption of differentiated sets of digital technologies and differentiated organisational tools also among firms in the same industry. However, only coherent resilience factors ensure that organisational routines and human and relational resources will support the digital transformation journey envisioned by decision makers. Our first research hypotheses can be therefore detailed as follows.

H1. Successful digital transformations may differ in technological configurations and organisation tools, provided that they are supported by a coherent bundle of resilience factors.

2.3 Resilience capacity, external complexity and strategy

Hypothesis 1 conditions variability in digital transformation to the coherence among organisation resilience factors. However, it provides no justification to the reasons that lead a firm to undertake a different digital transformation journey compared to competitors. Examining the relationship between resilience capacity, complexity of the external environment and strategic approach offers useful insights on this point.

Past studies have shown how organisations, and firms in particular, can turn external complexity into an asset by actively selecting and shaping their task environment (Ashmos *et al.*, 2000) and even by leveraging on external complexity to exploit their distinctive capabilities (Aitken *et al.*, 2016). However, the effectiveness of external complexity management depends on a range of internal and external factors, including decision-makers' perception and interpretation of reality (Boisot and Child, 1999), interaction rules and power distribution among internal agents (Ashmos *et al.*, 2002; Accard, 2019), external collaborations (Schneider *et al.*, 2017), and environment segmentation (Child and Rodrigues, 2011). External complexity and resilience capacity are therefore related concepts and the effectiveness of the strategies chosen to deal with the former strictly depends on the latter (Lengnick-Hall and Beck, 2005; Lengnick-Hall *et al.*, 2011; Dahlberg, 2015; Aitken *et al.*, 2016).

Boisot and Child's seminal paper (1999) identifies two alternative approaches to manage external complexity: complexity reduction and complexity absorption (Boisot and Child, 1999; Ashmos *et al.*, 2000; Walter and Bhuian, 2004). Complexity reduction is appropriate when decision makers perceive a low degree of variety in the external environment and frame change as a shift from a no longer sustainable equilibrium to a new one. Under those conditions, a simplified representation of the environment suffices to anticipate change and devise an effective strategy. In contrast, perception of high variability in the external environment due to substantial, continuous and unpredictable change drives towards complexity absorption. A strategy of complexity absorption requires the organisation to hold multiple (even conflicting) representations of the external environment and redundant resources to support a range of emergent routines and relations that provide strategic and operational flexibility under fluid conditions.

In more recent years, some researchers have questioned a dichotomous representation of the strategies available to manage external complexity, which may sound conceptually useful yet unrealistic (Child and Rodrigues, 2011; Dahlberg, 2015; Eloranta *et al.*, 2021). In line with this literature, we assume that complexity reduction and complexity absorption represent two extreme cases in a range of strategies. In addition, we assume that the specific mix of complexity reduction and complexity absorption carried out depends on the resilience capacity of an organisation. As resilience capacity increases, an organisation's ability to develop articulated representations of the external environment and to foreshadow consistent strategies and actions progressively gets more and more sophisticated. In other words, as resilience capacity increases, a company strategy will privilege complexity absorption over complexity reduction. The latter may therefore prevail among organisations with low resilience capacity, whereas more resilient organisations can choose in a range that spans from complexity reduction to the maximum degree of complexity absorption within their reach.

Digital technologies provide organisations with powerful tools to govern and adapt to external complexity (Luz Tortorella *et al.*, 2021). Accordingly, digital transformations can help firms in dealing with a competitive environment characterised by increasing uncertainty, change and interdependencies (Schroeder *et al.*, 2019; Pessot *et al.*, 2021). However, the literature on resilience and complexity suggests that to be successful a digital transformation has to support the deployment of a strategic approach aligned with the resilience capacity of the firm. In other words, in successful digital transformations the configuration of technological and organisational elements is functional to the mix of complexity reduction and complexity absorption designed to face the challenges of the chosen competitive environment. Variation in resilience capacity, hence in the perception of external conditions and in strategic approach, thus justifies why differentiated yet successful digital transformations can be observed in the real word. Our second research hypothesis summarises the above reasoning in the following statements.

H2. Successful digital transformations implement strategic approaches aligned with resilience capacity.

H2a. The lower the resilience capacity, the higher the probability that a successful digital transformation supports complexity reduction strategies.

H2b. The higher the resilience capacity, the higher the probability that a successful digital transformation supports complexity absorption strategies.

3. Methodology

The relationship between digital transformation, resilience capacity and complexity of the external environment was explored by means of a case study approach. Based on in-depth analysis, case studies allow investigating a phenomenon within the peculiar environment

where it develops (Yin, 2018). A case study approach is therefore particularly appropriate to appreciate resilience capacity, which cannot be separated from the context and the people it originates from (Branicki *et al.*, 2019). More specifically, this study adopts a multi-case method (Lijphart, 1975) based on three comparable firms that recently (up to two years before our interviews) started a digital transformation.

The three cases presented in this paper were selected from a wider set of ten manufacturing companies we interviewed as part of a research programme on the organisational impact of digital transformation. Company cases were chosen to match on variables not central to the research hypotheses, including membership in the valves industry, location in the same province of Northern Italy, a long familiarity with technological innovation and excellence in leveraging on innovation to support growth and economic performance. In addition, with the aim of limiting variance in adopted business models we focused on case companies where the digital transformation projects do not (yet) point towards servitisation. The sampled firms still differ in resilience capacity, digitalisation choices and competitive strategy, allowing for the emergence of relationships among those dimensions (Eisenhardt, 1989).

The three case studies, developed between late 2019 and early 2020, are primarily based on direct observation of production sites and semi-structured interviews with middle and top managers involved in the digital transformation. On-site visits by both the authors of this paper lasted between 45 min and 1.5 h, whereas semi-structured interviews lasted approximately one hour. The latter explored company and business characteristics, organisational resilience factors and digital transformation projects.

After each visit one of the participating researchers wrote down a detailed report based on field notes combined with additional information from internal sources (company brochures, magazines and web sites) and external sources (press articles, Internet videos, and public talks). Each written report was subsequently read and integrated by the other participating researcher and jointly discussed to outline key facts and solve diverging perceptions (Eisenhardt, 1989).

A set of meetings with local stakeholders, including the innovation delegate of an employers' association, trade union delegates, and the director of a technology innovation hub preceded on-site visits. These preliminary meetings helped focusing trends in digital transformation by local companies and identifying candidates to the case studies. Since all the three case companies invested in a Manufacturing Execution System (MES) [1] as part of their digital transformation, after completing the on-site visits an interview with the sales director of a local vendor of MESs provided additional information on typical firm attitudes and adoption patterns.

To obtain comparable information on the three case studies and test our research hypotheses we identified three sets of variables that describe the main characteristics of each case company (including competitive strategy and business model), their resilience factors and the undergoing digital transformations, respectively. The first set of variables (Table 1) include firm size, firm age, membership in an industrial group, output market features and organisation design. Since the recent history of each case company witnesses a change of business model to reposition in a higher market segment, output markets are characterised by contrasting traditional and new products. The organisation design is captured by organisation structure, prevailing approach to decision-making and management style.

The resilience capacity of case companies is characterised by the components of resilience factors (Table 2). We repeatedly examined written reports and field notes on each case study to outline statements and facts associated with cognitive, behavioural and contextual factors. Discussion among researchers based on systematic comparison between empirical evidence and the literature allowed deciding which pieces of evidence related with each component underlying resilience factors.

		Company Alpha	Company Beta	Company Gamma
Size [no. employees]		90	100	140
Foundation		1970s	1950s	1980s
Membership in an industrial group		Yes	Yes	No
Market	Traditional products	Water valves	LPG valves	Water valves, LPG valves
	New products	Oil and gas valves	Certified LPG valves	Hydrogen valves
Organisation	Organisation structure	Simple	Functional	Divisional with functional operations
	Decision-making	Centralised	Partially decentralised	Selectively decentralised
	Management style	Family-style	Formal	Participative

Table 1.
Main characteristics of the case companies

Resilience factors	Factor components	Company Alpha	Company Beta	Company Gamma
Cognitive factor	Organisation identity	Family business –3rd. generation Membership in an industrial corporation Lifelong employment International span, local roots Product quality and client service	Family business –3rd. generation Membership in an industrial corporation Employees' wellbeing International span, local roots Product quality and client service	Family business – 1st generation Lean production to raise participation Employees' wellbeing International span, local roots Product quality and client service
	Constructive sense-making	Family-centred management style Success history Technological excellence	Vertically integrated parent company Success history Technological excellence and innovation	Technological excellence and innovation Success history Participation
Behavioural factor	Routine repertoire	Formalisation focused on operations	Formalisation extended to coordination	Focus on knowledge codification (lean production)
	Functional habits	Limited by focus on control	Focus on R&D and integration	Focus on learning and participation
Contextual factor	Social capital	Focus on trust Internal labour market	Focus on skills and training Internal/external labour market	Focus on skills and training Mainly internal labour market
	Resource network	Input commodities from global suppliers Informal support by parent company	Key inputs from internal suppliers Extended network of clients and R&D partners	Demanding clients Extended network of R&D partners and consultants

Table 2.
Sources of resilience capacity at the case companies

The last set of variables focuses on the digital transformation undergoing at the case companies (Table 3). Relevant dimensions to capture the digital transformation include the decision-making process that led to the investment decision, the targets pursued, the contents of innovation projects, the characteristics of the implementation processes and the solutions to monitor the progress of implementation plans, and changes in organisation design and routines.

4. Three case studies

All companies examined are highly internationalised family businesses in the valves industry with operations based in an industrialised province of Northern Italy. With a turnover of 9 billion euros and 30,000 employees in 2019, the taps and valves industry is an important sector of Italian manufacturing (Prometeia, 2019). The strength of Italian companies in this industry is witnessed by the high share of exports (65% of turnover in 2019), yet competition is fierce due to the aggressive cost policy of producers from East Asia countries, the increasingly binding standards imposed by downstream clients such as utilities companies, and the raise of new application fields such as hydrogen valves. The following subsections report how each case company – henceforth Company Alpha, Company Beta and Company Gamma – has been exploring a distinctive path to the digital transformation to engage with the growing complexity of its competitive environment.

According to the definition provided in the first section of this paper, the digital transformation undertaken by all the three case companies can be defined as successful, because it significantly impacted operations and has been supporting business performance.

	Company Alpha	Company Beta	Company Gamma
Decision-makers	Company CEO and parent company top management	Company CEO and parent company top management	Company top management
Pursued targets	Efficiency increase; timely availability of shop-floor information	Efficiency increase; employees' wellbeing	Employees' wellbeing; efficiency increase
Adopted technologies	MES; automated warehouse	Integration between MES and ERP; highly automated assembly lines; collaborative robots	Integration between MES and ERP; integrated design and simulation software; 3D printers; machining centres with robotic loading and unloading
Organisation change	Limited to involved processes	New positions in operations; new organizational units, including a change management unit	Company-wide support to the lean-production approach
Implementation strategy	Working group including managers of involved functions; external consultants; centralised management and limited user involvement; limited training for users	External consultants and technical support from engineering group subsidiary; key-users early involvement; extensive training for users	Taskforce to outline the overall vision before launch of operative projects; external consultants; implementation teams including key users from involved units; steering committee to supervise coherence among projects; extensive training for users

Table 3.
Digital transformation at the case companies

In all cases interviewed managers reported high satisfaction with the investment and palpable, even if not yet quantified, positive impact on internal efficiency and product quality.

4.1 Company Alpha

Company Alpha traditionally produces made-to-stock steel ball valves and butterfly valves (Table 1). In recent years, due to price-based competition from East Asia companies, Alpha entered the market of made-to-order valves for the oil and gas sector, where suppliers need to comply with the stringent quality requirements imposed by oligopolistic clients in downstream markets. The business of standard valves is still sustainable thanks to the value added by pre- and post-sales services, yet profit margins are thinning and the efficiency of production process is getting increasingly important.

Company Alpha maintains close connections with the parent company, located few kilometres away and the CEO's membership in the family in control of the corporate group is not the only reason. The headquarters provide advice and financial support and organisational practices are informally shared among the group affiliates. The practice of lifelong employment, especially in the case of job-shop employees, also comes from the parent company and contributes to creating a "family-like" work environment.

Membership in a family business is a marking feature of Alpha's organisation identity, together with pride in the quality of provided products and services and the awareness of navigating a tricky competitive environment. Our interview detected coherent features of constructive sensemaking in the repeated allusions to technological excellence and a managerial style able to smooth internal tensions as the keystones to perpetuate past success (Table 2).

A comparatively simple organisation chart favours direct supervision and mutual adjustment over formal routines, which concentrate in operations and especially in fabrication, where automated machining centres set the pace of operations. A large dependence of inter-unit coordination on tacit informal routines and power centralisation in the strategic apex limit functional habits. Change management is a prerogative of the CEO, who coordinates with the parent company. Since most inputs to Company Alpha's processes are commodities sourced from global suppliers, the parent company represents the most critical external resource of the firm. Internal social capital centres on an internal labour market. For instance, workers are selected among local high school graduates below 25 years of age and higher vacant positions in operations are covered by internal promotions.

The digital transformation of Company Alpha (Table 3) was initiated by the CEO, who lamented 2-week lags in the availability of *ad hoc* reports on shop floor data, due to the centralisation of information collection and elaboration in the hands of the head of the planning department. Building on the available automated machinery and equipment, technological innovation centred on a new MES that allows for real-time automatic collection and elaboration of data from the fabrication workshop in contrast with past paper-based information. An automatic warehouse is still under implementation.

Interestingly enough, also the CEO had to comply with the company social norms and wait for the head of the planning department to retire before launching an investment that would otherwise affect the status of the employee formerly in charge of data analysis. Despite the obstacles met, the CEO reports full satisfaction with the new MES and acknowledges a significant increase in efficiency after its introduction. However, the new digital technologies involved limited change for the company routines. Real-time tracking of productivity-based monthly incentive via the new MES stimulates compliance by machine operators, who followed a short training course, but tasks and skills did not suffer significant alterations. No new positions or organisational units were created. In addition, in line with the CEO's original aims, use of the new MES for decision-making is mostly limited to the company managers.

4.2 Company Beta

Company Beta belongs to a vertically integrated corporate group that is world leader in equipment and components for gas control. Due to the increasing competitive pressure in lower market segments, Company Beta progressively focused on certified Liquefied Petroleum Gas (LPG) valves, which secure higher margins but impose strict quality standards that require more sophisticated design and production processes (Table 1).

Membership in a family corporate group deeply marks the organisational identity of the firm (Table 2). Beta's parent company was one of the pioneers in the LPG valves technology and the continuous search for technical excellence still marks constructive sense-making and shapes Company Beta's pro-active attitude towards technological change and market opportunities. Commitment to R&D is witnessed by involvement in research programmes with public research institutions and private companies.

Company Beta displays a functional organisation design that makes extensive use of formalisation to comply with required quality standards and manage a diversified range of products and internal processes. However, the company also adopts a selective decentralisation of decision-making to govern local variability. For instance, past waves of automation in operations progressively shifted shop floor workers' tasks from valves machining to output measurement and from valves assembly to process control. Company Beta therefore exhibits a behavioural resilience characterised by both a large repertoire of procedures to manage routine operations and an extended set of solutions and competences to approach transformation and change (Table 2).

Company Beta, which taps into both the internal and the external labour market to acquire the needed human resources, devotes significant effort to training programmes and runs an internal academy to provide technical and non-technical training. The parent company and the other subsidiaries represent Company Beta's most important partners and are critical components of its value chain. For instance, the group includes a subsidiary that produces die cast valves bodies and a subsidiary specialised in design and production of machines and equipment for LPG valves, which complements external technology vendors and can provide highly customised solutions.

The digital transformation journey undertaken to reposition in a higher segment of the market for LPG valves Company Beta involved an extended range of digital technologies (Table 3). As in the case of Company Alpha, a MES was integrated into the company Enterprise Resource Planning system. Additional investments include collaborative robots and highly automated assembly lines. Participation in a national multi-partner research programme on the digitisation of operations, where Company Beta leads the predictive maintenance work pack, confirms attention to the further development of digital competences.

A New Technologies corporate division was created to develop innovative services and solutions for the whole group. In 2016 Company Beta launched a new staff unit, the internet of Things (IoT) service. From the initial focus on new product development this staff unit progressively switched to governing and coordinating digital projects across all group divisions. This leading role emerged by means of a learning-by-doing process, driven by the interconnectedness that characterises digital processes and the technical skills recognised to the personnel of the IoT unit. Interaction between the IoT service and other units in digitalisation projects has led to the development of new skills and new negotiation dynamics. In turn, the stronger integration among units resulting from MES-supported information has been encouraging the development of new routines. For instance, the IoT service required production units to develop new quality handbooks.

Even if top management ruled the adoption processes, implementation encouraged users' involvement and empowerment, also by means of training. In most cases the automation of tasks in manufacturing lowered physical effort and involved jobs redesign based on job enrichment and job rotation. In general terms, the digital transformation at Company Beta

has accelerated the transition from mechanical skills to electronics and informatics skills and significantly shifted operation department heads' tasks from technical contents to personnel management. Outside operations, the IoT manager collaborates in enlarging the skills of the sales staff, who needed new competences in digital technologies to communicate the value added of the digital transformation.

4.3 Company Gamma

From the initial focus on made-to-stock and customised valves for utilities industries Company Gamma subsequently expanded to valves for the automobile industry, sub-contracting and, in the last decade, hydrogen valves (Table 1). Even in this case the shift reflects the will to lessen the pressure from cost-based competition in mature businesses by repositioning in a higher value-added although more demanding and uncertain segment of the valves market.

The organisational design of Company Gamma reflects the founder's vision of the firm as a social community based on participation. Jobs are ill-defined and positions may be created and cancelled according to contingent needs. Operations make extensive use of job rotation, teamworking and flash meetings. Improvement projects are frequently launched under the supervision of project managers appointed for their competence rather than hierarchic position. The engagement policy goes along with extensive technical and non-technical training, a corporate welfare system, profit-sharing incentives and a preference for internal candidates to fill in vacant positions. About ten years ago, the adoption of a lean production model further reinforced the company vision by placing additional emphasis on continuous improvement (Table 2).

Gamma's participative approach, markedly different from the more traditional vision prevailing among local employers, increases the company flexibility and reactivity to external challenges. However, participation imposes a burden that not all employees are willing to undertake. Despite pursuing an internal labour market policy Company Gamma suffers higher than average turnover rates. Exits from the R&D function intensified after the entry in the hydrogen valves sector, which has been imposing challenging targets upon researchers and designers.

The technological dimension of the digital transformation focused on three areas (Table 3): design and simulation software in the R&D department to anticipate problems in operations; new machining centres served by robots for automatic loading and unloading; and a new MES to integrate information from the shop floor and the Enterprise Requirement Planning system. Technological innovations answer the need for increased efficiency and costs control. However, Company Gamma's management claims that the primary motivation to invest laid in improving employees' wellbeing by reducing stress, fatigue and repetitive tasks. For this reason, for instance, changes in production privileged jobs enlargement over complete tasks automation.

Company Gamma is taking advantage of already existing functional habits to manage the digital transformation. A teamwork in charge of defining the overall vision behind the digital transformation anticipated the launch of operative projects, which involve key users from all affected areas selected based on individual motivation. All key users underwent training on project-specific technologies. In addition, a steering committee oversees the overall coherence of the digital projects undertaken by different areas of Company Gamma.

5. Discussion

This section reads the case studies presented above under the light of the research hypotheses detailed in section 2. For each hypothesis we will first present the supporting evidence from the case studies and subsequently discuss the theoretical and the practical implications of our findings.

5.1 Digital transformation and coherence among resilience factors

All the successful digital transformations examined display strong coherence among resilience factors (Lengnick-Hall and Beck, 2005; Lengnick-Hall *et al.*, 2011), which focus on centralisation in the case of Company Alpha, on planning and control for Company Beta and on participation for Company Gamma.

Direct supervision and face-to-face coordination substitute for a limited routine repertoire in Company Alpha. Overall coherence is ensured by shared values rooted in the internal labour market and in guidance by the parent company. Informal coordination and direct supervision provide Company Alpha with flexibility in case of limited change, whereas poor functional habits question the company resilience in front of a more robust and continuous change. Strong cohesion around the company values may nevertheless allow for a discontinuity, provided that modifications are sponsored by the CEO, supported by the parent company and compatible with the existing social capital.

The digital transformation of Company Alpha aligns with the features of organisational resilience capacity. The MES system and the automatic warehouse free resources to consolidate the entry in the market of made-to-order valves for the oil and gas industry. However, an organisational culture focused on centralisation and limited functional habits held back changes in power delegation and organisation design. In fact, information provided by the new MES was planned for use by the top management and the implementation of the digital transformation gave room to no further change.

An extensive range of routines to run day-to-day operations and plan change characterise Company Beta. Planning extends to the contextual dimensions of resilience, as witnessed by participation in long-term R&D partnerships and by the internal academy for the development of required competences. Resilience capacity is thus higher at Company Beta compared to Company Alpha and the former may successfully undergo more substantial change, provided it is carefully planned.

In line with resilience factors, the digital transformation had a wider scope in Company Beta not only because it involved both fabrication and assembly but also because it entailed job redesign for workers and supervisors in operations, the creation of additional organisation units, and the revision of existing procedures to take advantage of the opportunities opened up by the new technological solutions. Thanks to well-developed functional habits and focus on human resource development the company was able to internalise changes in power distribution and information flows in the routine repertoire. In addition, focus on systematic planning and control helps the company to rationalise and make sense of unexpected outcomes of innovation *a posteriori*, as in the progressive extension of the tasks officially assigned to the Internet-of-Things unit.

Company Gamma displays an intense development of all resilience factors. The cognitive resilience of Company Gamma centres on participation, with a substantial alignment between organisational identity and constructive sensemaking. If the former builds on the innovativeness and product quality based on members' engagement, the latter explicitly connects the company success to a technological performance rooted in participation. Thanks to intense vertical and horizontal communication, decentralised decision-making, and a lean approach to manufacturing the company benefits from a wide repertoire of standard routines and meta-routines for continuous improvement and change management.

The focus on participation that characterises the resilience capacity of Company Gamma resulted in the adoption of digital solutions oriented to job redesign in support of employees' self-activation, as in the case of shop floor selective automation. The adoption of advanced simulation tools such as digital twins in product and process design reflected the capability to integrate complex innovations in the company routines, also thanks to the practice of participative teams in project deployment.

The above evidence confirms our first research hypothesis on the feasibility of differentiated paths to the digital transformation, provided they are supported by a coherent bundle of resilience factors. Our analysis corroborates the opportunity to leverage on the construct of resilience to explain the antecedents and the deployment of change processes (Cotta and Salvador, 2020; Luz Tortorella *et al.*, 2021; Polyviou *et al.*, 2020). Resilience capacity encompasses a set of interconnected enabling factors and drivers (Bosman *et al.*, 2020) separately addressed by specific approaches such as the socio-technical approach (Cimini *et al.*, 2021; Savastano *et al.*, 2022) and the dynamic capabilities theory (Demeter *et al.*, 2021). The construct of resilience therefore answers the need for a more holistic approach the literature has been hoping for in the case of technological and organisational change in general and the digital transformation in particular (Demeter *et al.*, 2021; Imran *et al.*, 2021). In addition, if the literature has stressed that organisational resilience is a measurable construct rather than an on-off property (Dahlberg, 2015; Hillmann and Guenther, 2021), our empirical analysis adds that thriving under challenging conditions is not limited to the most resilient organisations, provided that coherence exists among all resilience factors.

Evidence that a successful digital transformation aligns with the resilience capacity of the firm has important implications also for managerial practices. First, a harmonious growth of resilience factors has a stronger impact on the success of a digital transformation than investing in the development of a single component or factor. For instance, Company Beta can take full advantage of its intense R&D partnerships thanks to a vast set of routines to internalise the outcomes of external collaborations. In contrast, the lack of a systematic approach to relationship management may lessen the benefits of a strategic alliance outside the perimeter of the industrial group in the case of Company Alpha. Second, firms should avoid the adoption of fashionable digital solutions in favour of configurations that actually align with organisation sensemaking (Sanchez-Riofrio *et al.*, 2021). Firm-specific approaches are needed to reflect the non-linear relationship between strategic planning and strategy deployment when digital technologies are involved (Li, 2020).

5.2 Digital transformation and external complexity

Each case company stepped into a digital transformation in support of a company-specific strategy aimed at new competitive challenges. Company Alpha has been using technological innovation to increase internal efficiency and free resources to move into a higher value-added market segment, new to the company yet comparatively mature. In Company Beta the digital transformation is meant to increase product and process quality and compete in the most demanding segment of the LPG valves market. Eventually, Company Gamma frames the digital transformation as a further tool to stretch its lean production approach and consolidate its technological leadership in hydrogen valves production.

Despite common focus on change management, the three case companies are using the digital transformation to face different competitive challenges and pursue different business targets. The complexity of the external environment changes with the chosen goals and increases from Company Alpha to Beta to Gamma, in line with resilience capacity.

The empirical evidence summarised in Table 4 shows that all case companies use digital technologies and associated organisational change to support a mix of actions oriented both to complexity reduction and complexity absorption. However, the resort to complexity absorption increases with the complexity of the external environment and organisational resilience capacity from Company Alpha to Beta to Gamma, thus confirming our second research hypothesis.

	Complexity reduction	Complexity absorption
Company Alpha	• Substitution of human labour in fabrication • Substitution of human labour in warehouse • Clearer detection of problem roots • Predictable information flows from shopfloor to strategic apex	• More timely information to top management
Company Beta	• Substitution of human labour in fabrication • Substitution of human labour in assembly	• Redesign of operative jobs to add control and management tasks • New roles • New organisation units to exploit business opportunities
Company Gamma	• Substitution of human labour in fabrication • Substitution of human labour in assembly	• Explicit vision to ensure coherence across digital transformation projects • Redesign of operative jobs to add control and management tasks • Digital technologies in support of R&D and process design • Top-down, bottom-up and horizontal information flows

Table 4.
Digital transformation to implement complexity reduction and complexity absorption strategies

This finding contributes to the existing literature by questioning a binary view of the strategy that an organisation may adopt to approach external complexity (Boisot and Child, 1999). Firm-level strategies rather involve a blend of actions that target both complexity reduction and complexity absorption. Some evidence in this direction already exists in the case of servitisation based on digital technologies (Eloranta *et al.*, 2021). However, our study takes a further step by suggesting that resilience capacity plays a discriminating role in orienting a prevalence of either complexity reduction or complexity absorption in the mix of actions undertaken by firms.

The acknowledgement that a company may undergo differentiated digital transformations depending on chosen business targets and strategies denies technological determinism and supports the existence of heterogeneous behaviours across firms (Hirsch-Kreinsen, 2016; Bosman *et al.*, 2020; Nayernia *et al.*, 2021) also due to complementarities and unforeseen interactions among adopted technologies (Frank *et al.*, 2019).

The refusal of technological determinism implies that also in the case of digital transformations technological maturity does not depend on the range or the intensity of adopted technologies, but rather on the capability to select the configuration of technological and organisational tools that enhances the probability to meet the intended competitive challenges (Lengnick-Hall and Beck, 2005; Boisot and Child, 1999).

Awareness that resilience capacity shapes the strategies available to engage with external complexity should focus companies to invest in the reinforcement and the alignment of resilience factors. This may help firms increase their understanding of external challenges and compose the best mix of technological and non-technological tools to improve the chances of success of the digital transformations undertaken.

6. Conclusions

By reading three case studies of digital transformation under the lens of resilience our research shows that variability in the resilience capacity of firms and differences in the

complexity of the chosen external environment justify differentiated paths to a successful digital transformation, provided that coherence exists among resilience factors.

Company Alpha displays a lower level of resilience capacity compared to the more structured and better endowed Company Beta, and even lower in comparison with participative Company Gamma. However, in all cases the deployment of a digital transformation functional to the pursued business model corresponds to an internal coherence between cognitive, behavioural and contextual factors.

When resilience capacity is low, technological change is centrally governed and organisational adjustments are limited. In this case, exemplified by Company Alpha, the digital transformation privileges a strategy of complexity reduction over complexity absorption. In contrast, when a higher resilience capacity allows for engaging with continuous and unpredictable change, the digital transformation involves more decentralised decision-making and significant organisational change. Both Company Beta and Company Gamma favour complexity absorption to face competitive challenges. However, whereas the former exploits substantial internal and external resources to reinforce its competitive position in a premium segment of its traditional business, the latter leverages on organisation and workforce flexibility to diversify in an innovative market new to the company.

From a theoretical point of view, our paper identifies in organisational resilience a holistic approach that simultaneously accounts for the technological, organisational, strategic and environmental factors affecting the digital transformation journey (Demeter *et al.*, 2021; Imran *et al.*, 2021). In addition, our analysis leverages on resilience capacity to support previous criticisms to a binary view of strategic approaches to complexity management (Eloranta *et al.*, 2021). The continuous nature of resilience capacity reflects into no clear-cut separation between complexity reduction and complexity absorption strategies and justifies the existence of diversified paths to the digital transformation.

Our analysis bears significant implications also for practitioners. Diversified paths to digital transformation are possible. However, empirical support to the first research hypothesis stresses the importance of investing in coherence among resilience factors to increase the probability of success of a digital transformation. Moreover, empirical support to the second research hypothesis suggests that the implementation of strategies that leverage on digital transformation to face highly complex and challenging situations require investing to intensify resilience factors and overall resilience capacity.

Further research may test the generalisability of our findings to a wider range of industries and firm sizes. An additional limitation of our research stays in the cross-sectional nature of the case studies explored (Demeter *et al.*, 2021). Future research involving the development of longitudinal case studies may explicitly address the dynamic and path-dependent nature of resilience factors. In the examples examined in this paper the combination of cognitive, behavioural and contextual factors, and the resulting resilience capacity, is not random. It rather composes a coherent picture of internal variety, where resources and cognitive tools enable the design and the enactment of consistent routines and meta-routines. Still, alignment among the components of organisational resilience cannot be taken for granted (Chen *et al.*, 2021). Resilience factors may structure and evolve according to different configurations, not necessarily consistent. Understanding which drivers favour their harmonic development and how different stakeholders may affect this process would provide additional useful insights to researchers and practitioners.

Note

1. A MES is a software to collect and manage operations data in manufacturing firms. Machines and equipment sensors generate bottom-up flows of information that the MES transfers to a higher-level information system such as an Enterprise Requirement Programme (ERP), whereas top-down directives are implemented by means of distributed actuators.

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