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

Lino Codara

DIMI, Università degli Studi di Brescia (I)
Via Branze, 38 – 25123 Brescia (Italy)
E-mail: lino.codara@unibs.it

Francesca Sgobbi *

DIMI, Università degli Studi di Brescia (I)
and
DINÂMIA'CET, ISCTE-IUL (P).
Via Branze, 38 – 25123 Brescia (Italy)
E-mail: francesca.sgobbi@unibs.it

** Corresponding author*

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Abstract

How can firms leverage on digital technologies to improve their survival odds in a challenging and competitive environment? And what explains the differences observed in adoption paths and usage patterns? This paper resorts to the concepts of resilience and complexity to justify the existence of differentiated yet effective approaches to the digital transformation by contrasting the success stories of three Italian companies in the valves industry. The hypothesis underlying this study is that digital technologies aligned with the resilience level of the adopting organisation support an appropriate engagement with the complexity of the external environment. The case studies of digital transformation examined point out two main findings. First, for all companies the digital transformation represents an evolutionary rather than a revolutionary process. Second, in successful companies the digital transformation is coherent with internal resilience level and external complexity.

Keywords – Digital transformation, Resilience, Complexity, Organisational change, Case studies

1 Introduction

The digital transformation is probably the most pervasive innovation of the last decades. Despite some concerns on the possible negative consequences for the mid- and low-skilled workforce, there is a widespread agreement on the importance of digital technol-

ogies in support of firm competitiveness and innovativeness (Brynjolfsson and McAfee, 2014; European Commission, 2019). However, systematic evidence on which conditions turn the adoption of digital technologies at the firm level into a successful growth path is still lacking. In addition, existing information suggests that adoption timing and mode, usage patterns, and impact on internal organisation widely vary across firms (Kiel *et al.*, 2017; Butollo *et al.*, 2018; Codara and Sgobbi, 2020; Götz and Jankowska, 2020). What justifies those differences? And how could firms leverage on digital technologies to improve their survival odds in a challenging and competitive environment? The empirical analysis in this paper shows that the constructs of resilience and complexity may help answering these questions. Defined as the capability to recover from a one-time shock or thrive under frequent, eventually continuous significant and unpredictable change (Manyena *et al.*, 2011), 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. Resilience is therefore a powerful asset to navigate a complex external environment characterised by dynamic and unpredictable relationships among diverse players and forces (Ashmos *et al.*, 2000).

This paper illustrates the reasons behind the existence of different effective approaches to the digital transformation by contrasting the stories of three Italian companies in the valves industry. The underlying hypothesis is that successful firms configure digital technologies according to their resilience level to improve the probability of choosing a strategy that matches external complexity. Different technological solutions may prove valuable, provided that they align with the company resilience level and the complexity of the external environment.

The case studies examined support the research hypothesis. The higher the resilience level, the more frequent the use of digital technologies in support of decentralised decision-making and organisational change, and the higher the complexity of the competitive environment the company can engage with.

The rest of the paper is organised as follows. Section 2 sets out the research hypothesis based on key suggestions from the literature on organisational resilience and complexity. 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 outlines further research lines.

2 Digital technologies, complexity, and resilience

The diffusion of digital technologies has revived the debate on the relationship between organisations and their external environment. One the one hand, by increasing interdependencies the digital transformation raises external complexity (Child and McGrath, 2001; Schroeder *et al.*, 2019). On the other one, digital technologies provide organisations with powerful tools to govern and adapt to external complexity (Tortorella *et al.*, 2021).

Past literature has 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; Daft, 2015) and even by leveraging on external complexity to exploit their distinctive capabilities (Aitken *et al.*, 2016). Decision makers' perception and interpretation of reality crucially shape engagement with the external environment because strategies and actions are undertaken based on representations and understanding of external complexity rather than objective measures (Boisot and Child, 1999). Richer perceptions and more varied representations of the environment increase the probability that purposive action taken by key organisational actors will actually match the features of the external complexity.

A range of internal and external factors affect decision makers' interpretive processes, including 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). A comprehensive framework to connect all those drivers and their interactions is provided by the construct of resilience (Lengnick-Hall and Beck, 2005; Lengnick-Hall *et al.,* 2011). According to Lengnick-Hall and Beck (2005), organisational resilience results from the composition of interpretive capabilities (cognitive factors), routines and structures (behavioural factors), and resources (contextual factors)[1].

[1] Lengnick-Hall and Beck (2005) outline a model of organisational that resilience allows for a multifaceted understanding of an organisation approach to external complexity. First, the authors underline how interpretive capabilities alone are not enough to engage with the external environment. Second, by disentangling the behavioural and the contextual dimensions of resilience the model stresses that the en-

Lengnick-Hall and Beck suggest that resilience is more than the sum of its components. Resilience increases with the coherent growth of its underlying factors, which interact according to non-linear and non-strictly predictable patterns. The higher the resilience level, the wider the scale and the scope of change an organisation can identify, select, and successfully master. Accordingly, more resilient organisations benefit from a higher probability to select an approach to external complexity that matches actual environment conditions (Lengnick-Hall and Beck, 2005; Lengnick-Hall *et al.,* 2011).

The literature has identified complexity reduction and complexity absorption as two archetypal approaches to external complexity (Boisot and Child, 1999). 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. In this case, a simplified representation of the environment suffices to anticipate change and devise a strategy to achieve a new equilibrium. In contrast, when the external environment is perceived as highly variable and change is consistent and continuous, complexity absorption is the most effective response. A strategy based on complexity absorption requires the organisation to hold multiple (even conflicting) representations of its environment and an endowment of redundant resources to support a range of emergent routines and relations that provide strategical and operational flexibility under fluid conditions. According to the literature on complex systems, the degree of organisational resilience is therefore a proxy for internal complexity to be matched with external complexity.

Complexity reduction and complexity absorption are typically presented as distinct, alternative approaches (Boisot and Child, 1999; Ashmos *et al.*, 2000; Walters and Bhuian, 2004). However, a dichotomous representation of the strategies available to face external complexity may sound conceptually useful, yet unrealistic (Child and Rodrigues, 2011). Complexity reduction and complexity absorption may rather represent two extreme cases. The composition of the cognitive, behavioural, and contextual properties of an organisation defines different levels of resilience and therefore different degrees of complexity in context representation, viable strategies, and actual choices. Ac-

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actment of routines and structure requires appropriate internal and external resources. Third, by including both current routines and the procedures to change current routines among behavioural factors the model jointly considers the knowledge exploiting and the knowledge exploring mechanisms that take place within an organisation (March, 1991; Boisot and Child, 1999).

cordingly, companies adopt strategies that include a mix of complexity reduction and complexity absorption. Real organisations position along a continuum that ranges from unique and stable representations of reality, corresponding to simplified strategies, to multiple and variable representations that support highly complex action plans. As the level of resilience increases, an organisation's ability to develop multiple representations of the environment and to foreshadow strategies and actions progressively gets more and more sophisticated. In other words, as the level of resilience increases, a company strategy will progressively overcome the complexity reduction approach and get closer to complexity absorption. Complexity reduction may therefore represent the prevailing strategy perceived by less resilient organisations, whereas more resilient ones can choose in a range that spans from complexity reduction to the maximum degree of complexity absorption within their reach.

As in the case of past waves of technological innovation, also digital technologies provide new tools to face competitive challenges. Our hypothesis is that successful firms configure digital technologies according to their resilience level to improve the probability of choosing a strategy that matches external complexity.

3 Methodology

The relationship between digital technologies, resilience, and environmental complexity 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. A case study approach is therefore particularly appropriate to appreciate organisational resilience, which cannot be separated from the environment 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 adopted a bundle of digital technologies. The examined firms match on variables not central to the research hypothesis, including membership in the valves industry, a long familiarity with technological innovation, and an excellent capability to leverage on innovation in support of growth and economic performance. However, the sampled firms differ in resilience capability, digital policies, and competitive strategy, allowing for an assessment of the relationship among those dimensions.

The case studies, developed between late 2019 and early 2020, are based on direct observation of production sites, semi-structured interviews with middle and top managers involved in technology adoption, internal brochures, company magazines, company web sites, and external documents such as press articles, Internet videos, and public talks. Besides information on structural characteristics and output markets, collected data concerned two additional areas: the components of organisation resilience and the digital transformation projects.

We operationalise the construct of resilience based on Lengnick-Hall and Beck (2005), who frame resilience as a combination of cognitive, behavioural, and contextual factors. Each basic factor is further decomposed in two additional elements. The cognitive component of resilience 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 imply both understanding and emotion" (Lengnick-Hall *et al.*, 2011, p.246). Collected information outlined the values and the vision that shape each organisation's identity and those elements of sensemaking (guidelines rooted in the company's culture, managerial style, past experiences) that affect organisational propensity to innovation and change.

The behavioural dimension of organisational resilience, which turns cognitive properties into visible actions, includes two components: the inventory of operational routines, which govern day-by-day operations, and functional habits, which consist of the generative meta-routines (Zamarian, 2010) to create and modify operational routines. Both routines and meta-routines are linked to internal variety and to the orientation of organisation design. On the one hand internal variety (captured by products diversification and the heterogeneity of internal processes and organisation units) is proportional to the number and the diversity of operational routines. In turn, the need for changing those routines is proportional to tensions and conflicts among groups and units competing for the same (limited) resources, which increase with internal variety (Größler *et al.*, 2006). On the other hand, also organisation design shapes internal routines and their change, as exemplified by the well-known opposition between organisations designed

for efficiency and organisations designed for learning (Daft, 2015). In efficiency-oriented organisations a vertical structure based on strict hierarchy, centralised decision-making, and limited use of teamwork increases the formalisation of tasks and processes, the number of detailed routines to manage day-by-day operations, and resistance to change. In contrast, learning organisations favour a horizontal structure characterised by more relaxed hierarchy, decentralised and participative decision-making, horizontal information flows, inter-functional work teams, and liaison roles, therefore supporting more complex and varied functional habits and more creative response to change.

The third component of organisational resilience, contextual resilience, allows for integrating cognitive and behavioural resilience and includes social capital and resources network. "Deep social capital evolves from repeated, personal interactions between people and between organizations and is most effective when based on trust" (Lengnick-Hall and Beck, 2005, p.752). The social capital of the observed companies was measured based on the use of practices that promote mutual trust and the "ability of participants … to subordinate individual goals and associated actions to collective goals and actions" (Leana and Van Buren, 1999, p.541). Those practices include participation tools, training, personnel retention policies, and collaborative work. In a similar way, resource networks were assessed via the extension and the intensity of interdependent relationships with external agents such as affiliates, suppliers, customers, research centres, and institutions.

The last set of variables examined in the case studies concerns the adoption of digital technologies. The interviews explored the contents of innovation projects, the degree of decentralisation in associated decision-making, employees' involvement, the solutions to monitor the progress of implementation plans, and possible changes in organisation design. Thanks to significant differences among the examined companies, the collected information allows assessing the coherence among the nature of the involved technological solutions, firm resilience level as shaped by cognitive, behavioural, and contextual factors, and the complexity of the external environment where companies choose to compete.

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 aggressiveness of low-cost producers from Far East countries, the more and more binding standards imposed by downstream clients such as utilities companies, and the raise of new application fields, as in the case of hydrogen valves. The following subsections report how the examined companies – henceforth Company Alpha, Company Beta, and Company Gamma – have been exploring distinctive paths to turn digital technologies into a tool for engaging with the complexity of their external environment. Table 1, Table 2, and Table 3 summarise the key elements of the three case studies by comparing firm characteristics (Table 1), sources of organisational resilience (Table 2), and investments in digital technologies (Table 3).

4.1 Company Alpha

Company Alpha was founded in the 1970s as a branch of a taps and fittings parent company to produce made-to-stock steel ball valves and butterfly valves. In recent years, due to price-based competition from Far East companies, Alpha entered the market of made-to-order valves for the oil and gas sector, where suppliers need to comply with the strict certification processes imposed by large clients. In 2019 oil and gas valves represented 1% of produced volumes but accounted for 20% of turnover. The business of standard valves is still sustainable thanks to the value added by pre- and post-sales services, which allow for a price premium compared to products from low-labour cost countries. The production of both standard and made-to-order valves include two main phases, allocated to separate job-shops: highly automated fabrication and labour-intensive assembling and testing. Company Alpha employs about 90 employees and exports account for 45% of turnover.

Company Alpha maintains close connections with the parent company, located few kilometres away, and CEO's membership in the family in control of the industrial group is not the only reason. The headquarters provide advice and financial support for exter-

nal consultancies and technological and real estate investments. In addition, organisational practices are informally shared among the group affiliates. For instance, an incentive plan agreed with the trade unions at the parent company was extended to subsidiaries where trade unions are not present, Alpha included, to avoid feelings of unfair treatment. 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 atmosphere".

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. The case study interviews detected coherent features of constructive sensemaking in the repeated allusions to technological excellence and a managerial style able to smooth tensions as the keystones to perpetuate past success.

The comparatively simple organisation chart favours direct supervision and mutual adjustment over formal routines, which concentrate in production processes 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 the concentration of decision power in the strategic apex, with selective delegation to the heads of the organisational units, 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 important external resource of the firm. Internal social capital centres on the internal labour market. For instance, workers are selected among local high school diplomates below 25 years of age and higher vacant positions in operations are covered by internal promotions.

The resilience factors described above sketch a coherent picture. Thanks to informal coordination and direct supervision Company Alpha can provide a flexible answer in case of limited change, whereas poor functional habits question the company resilience in front of more robust and continuous change. However, strong cohesion around the company values may enable a discontinuity, provided that modifications are sponsored by the CEO, supported by the parent company, and compatible with the existing social capital.

Not surprisingly, the digital transformation of Company Alpha 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 availability of automated machinery and equipment, technological innovation centred on a new Manufacturing Execution System (MES) that allows for real-time automatic collection and elaboration of data from the fabrication workshop. In contrast with past paper-based information, data on production pace, set ups, and down-time for each machining centre are immediately available for workers, who can check delays on programmed plans via large displays across the workshop, for supervisors, who benefit from easier end-shift handover, and, above all, for top managers, who can either consult standard reports or access raw data to build customised indicators.

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 prestige 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 technology had limited impact on company routines. Compliance by machine operators, who followed a brief training course, was stimulated by immediate tracking of their production-based monthly bonus via the new MES, but tasks and skills did not suffer significant alterations. No new positions or new organisational units were created. In addition, the MES supports decision-making mainly in the case of managers. In summary, the adoption of new digital technologies at Company Alpha answers a need for increasing the efficiency of the existing processes rather than redefining and integrating the overall organisation design. The lack of radical structural changes and the persistence of centralised control suggest that Company Alpha is using digital technologies to overcome the difficulties posed by increased competition in search of a new equilibrium rather than to pursue continuous change.

4.2 Company Beta

Founded in the 1950s, Company Beta belongs to a vertically integrated corporate group that is world leader in equipment and components for gas control. Company Beta manu-

factures Liquified Petroleum Gas (LPG) valves that other subsidiaries of the group sell to multinational oil corporations and LPG cylinder producers in over 150 countries. Due to the increasing competitive pressure in lower market segments, Company Beta progressively focused on certified LPG valves, which secure higher margins but impose strict quality standards that require more sophisticated design and production processes.

Company Beta's resilience builds on several factors, including a multidecade-long history of R&D and technical excellence in the LPG valves technology, the parent company's leadership in the field, the capability to manage a high variety of products, processes, and customers, and a consolidated focus on effectiveness and learning. Membership in a family corporate group deeply marks the organisational identity of the firm. 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. This attention is witnessed by involvement in research programmes with public research centres and private companies.

Company Beta displays a functional organisation design with an extensive use of formalisation to comply with required quality standards, but also a selective decentralisation of decision-making to govern local variability. For instance, past waves of automation in operations progressively shifted the tasks of direct workers 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.

Company Beta, which taps into both the internal and the external labour market to acquire the needed human resources, devotes significant efforts to training programmes, as witnessed by the launch of an internal academy providing 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 diecast valves bodies and a subsidiary specialised in design and production of machines and equipment for the production of LPG valves, which complements solutions from external technology vendors and can provide highly customised solutions. The key role played by the industrial corporation in shap-

ing Company Beta's resource network is witnessed by the corporate monthly technical magazine, which communicates technical innovations and business opportunities to clients, suppliers, and research centres.

To reposition in a higher segment of the market for LPG valves where it already operated, Company Beta adopted an extended range of digital technologies. As in the case of Company Alpha, a MES was integrated into the company Enterprise Resource Planning system to collect timely and reliable information from the fabrication and the assembly job-shops in order to reduce waste and increase product quality. Additional investments aimed at increasing efficiency and reducing the repetitiveness of operators' tasks include collaborative robots and highly automated assembly lines. Company Beta is further developing its digital competences by participating in a national multi-partner research programme targeted at the digitisation of the entire production cycle, where it is in charge of predictive maintenance design.

The digital transformation of Company Beta displays high coherence with the firm's resilience factors. Thanks to well-developed functional habits the company was able to absorb the increase in internal variety by means of new organisational units and change in job contents. At the corporate level a New Technologies division was created to develop innovative services and solutions for the whole group. In 2016 a new staff unit, the Internet of Things (IoT) service, was launched. From the initial focus on product-specific R&D, 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. The need to interact with the IoT service and with other units in digitalisation projects has led to the development of new skills and negotiation dynamics. The IoT service manager always participates in negotiates with customers because the management of Company Beta has noticed that a shared technical language improves communication. The development of new routines is associated also to a stronger integration among units encouraged by the availability of new information on operation-level processes. For instance, the IoT service required production units to develop new quality handbooks.

Even if top management ruled adoption processes, implementation encouraged users' involvement and empowerment, also by means of training. In most cases the auto-

mation of manufacturing tasks lowered physical effort for operators and involved jobs redesign based on job enrichment and job rotation. In general terms, the adoption of digital technologies at Company Beta accelerated the transition from mechanical skills to electronic skills and significantly shifted the tasks of operation department heads from technical contents to personnel management. Outside operations, the IoT manager collaborated in enlarging the skills of the sales staff, who needed new competences in digital technologies to communicate the value added of digital investments in business negotiates.

Rather than exploiting already beaten roads Company Beta explores change opportunities thanks to comparably high resilience level. Based on internal cognitive, behavioural, and contextual resilience digital technologies create more suitable conditions to engage in continuous change. By leveraging on technological change, the company thus privileges complexity absorption over complexity reduction to thrive under uncertain conditions.

4.3 Company Gamma

Company Gamma was founded in the early 1980s and has since consolidated a reputation for producing made-to-stock and customised valves for utilities industries. Production subsequently expanded to valves for the automobile industry, subcontracting and, in the last decade, hydrogen valves. The latter move reflects a willingness to build on the company traditional strengths to reposition in a higher value-added despite more demanding and uncertain segment of the valves market to lessen the pressure from cost-based competition in mature businesses. Each product line corresponds to a business unit with dedicated sales, purchases, and quality control functions. R&D, support staff, and operations serve all business units. Company Gamma employs about 180 employees, including 40 R&D engineers.

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. Job rotation, teamworking, and flash meetings are extensively used in operations. Improvement projects are frequently launched under the supervision of project managers appointed for their competence rather than hierarchic position. Those project managers, who answer to top man-

agers, autonomously select the members of their support team. The engagement policy is accompanied by diffused 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 mode further reinforced the company vision by placing additional emphasis on continuous improvement.

Gamma's managers acknowledge that an approach to human resources based on participation, markedly different from the more traditional vision prevailing among local employers, increase the company flexibility and reactivity to external challenges. However, participation imposes a burden that not all employees are willing to undertake. Despite the internal market policy Company Gamma witnesses 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.

Firm characteristics outline a coherent and intense development of resilience factors at Company Gamma. Cognitive resilience centres on participation, with a substantial alignment between organisational identity and constructive sensemaking. If the former builds on the innovativeness and the quality of products and services deriving from firm 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. In addition, Company Gamma has been investing in the development of internal and the external resources to support engagement with a competitive environment perceived as complex and challenging. On the one hand the company social capital has been the target of sustained investments, on the other hand Company Gamma benefits from relationships with clients that represent the state-of-the-art of technology and from an extended network of R&D partners and consultants.

The observed digital transformation reflects the resilience level of the firm also in this case study. Investment in digital technologies focused on three areas: design and simulation software in the R&D department to anticipate problems in production and working conditions; new machining centres served by robots for automatic loading and

unloading operations; and a new MES to integrate information from the shop floor and the Enterprise Requirement Planning (ERP) 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 increasing employees' wellbeing by reducing stress, fatigue, and repetitive tasks in all affected departments. For this reason, for instance, changes in production privileged the enlargement of workers' tasks over complete automation.

A teamwork in charge of defining the overall vision behind the digital transformation anticipated the launch of operative projects, which involved key users from all affected areas selected based on individual motivation. All key users were offered training on project-specific technologies. A steering committee is responsible for the overall coherence of the digital projects undertaken by different areas of Company Gamma.

Company Gamma shares with Company Beta the resort to digital technologies to absorb external complexity, which in this case is driven by entry in the highly innovative market segment of hydrogen valves. However, in the case of Company Gamma the use of new technologies in search for greater efficiency and flexibility has been accompanied by a constant attention to expanding the workforce autonomy, reducing physical fatigue, and providing new tools and opportunities to involve all company employees in designing and implementing innovative solutions. We may therefore suggest that the digital transformation leverages on the remarkable resilience level of Company Gamma to allow for the absorption of a high degree of external complexity.

5 Conclusions

Based on on-site visits, interviews with managers, and available documents the cases studied in this paper provide successful examples of digital transformation. Our analysis points out two main empirical findings. First, for all companies the digital transformation represents an evolutionary rather than a revolutionary process. A habit of technological excellence rooted in market competition is still a powerful driver to adopt state-of-the-art solutions also in the knowledge economy.

Second, the successful firms examined confirm our research hypothesis by displaying configurations of digital technologies that align with internal resilience level and external complexity. When the company resilience level is limited technological change is

centrally governed and involves narrow organisation adjustments. 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 level 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 privilege complexity absorption to face competitive challenges. However, whereas the former exploits large internal and external resources to reinforce its 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. The continuous nature of resilience reflects into no clear-cut separation between complexity reduction and complexity absorption strategies and justifies the existence of diversified paths to the digital transformation.

The main limitation of our research stays in the cross-sectional nature of reported case studies. Future research involving the development of longitudinal case studies may explicitly address the dynamic and path-dependent nature of resilience factors. In the successful examples examined in this paper the combination of cognitive, behavioural, and contextual factors, and the resulting resilience level, 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. In the examples presented above Company Alpha displays a lower level of resilience compared to the more structured and better endowed Company Beta, and even lower in comparison with participative Company Gamma. However, resilience factors may structure and evolve according to different configurations, not necessarily consistent. Understanding what drivers favour their harmonic development and how different stakeholders may affect this process would provide useful insights to researchers and practitioners.

A diachronic approach to the relationship between digital transformation, resilience capability, and engagement with the external environment at the company level could also throw new light on the dynamic relationships among the considered factors. New research may explore how success or failure in digital transformation transform the resilience capability of a company and the balance between complexity reduction and complexity absorption in adopted strategies.

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Table 1. Main characteristics of the surveyed companies

		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 & 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 2. Sources of organisational resilience of the surveyed companies

		Company Alpha	*Company Beta*	*Company Gamma*
Cognitive properties	Organisation identity	Family business – 3rd generation	Family business – 3rd generation	Family business – 1st generation
		Membership in an industrial corporation	Membership in an industrial corporation	Lean production to raise participation
		Lifelong employment	Employees' wellbeing	Employees' wellbeing
		International span, local roots	International span, local roots	International span, local roots
		Product quality and client service	Product quality and client service	Product quality and client service
	Constructive sense-making	Family-centred management style	Vertically integrated parent company	Technological excellence and innovation
		Success history	Success history	Success history
		Technological excellence	Technological excellence and innovation	Participation
Behavioural properties	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 properties	Social capital	Focus on trust	Focus on skills and training	Focus on skills and training
		Internal labour market	Internal/external labour market	Mainly internal labour market
	Resource network	Input commodities from global suppliers	Key inputs from internal suppliers	Demanding clients
		Informal support by parent company	Extended network of clients and R&D partners	Extended network of R&D partners and consultants

Table 3. Main feature of the investments in digital technologies

	Company Alpha	*Company Beta*	*Company Gamma*
Decision-maker	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
Innovation scope	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; training for users	Launch of operative projects preceded by a taskforce to outline the overall vision; external consultants; implementation teams including key users from involved units; steering committee to supervise coherence among projects; training for users