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The Role of External Actors in SMEs' Human-Centered Industry 4.0 Adoption: An Empirical Perspective on Italian Competence Centers

Beatrice Ietto, Chiara Ancillai, Andrea Sabatini, Elias G. Carayannis, Gian Luca Gregori

***Abstract*— Despite the many benefits associated with the Industry 4.0 megatrend, researchers and practitioners alike have warned against an overly technocentric implementation of such a paradigm. Industry 4.0 should be corroborated by an awareness of its wider social implications, otherwise it might threaten human and societal well-being. Notably, firms should innovate and maintain competitiveness by respecting human values and developing collaborative relationships between humans and robots, while improving the wider societal well-being as well as recognizing ethical and socio-cultural factors. Yet, firms, especially small and medium enterprises (SMEs), face several challenges concerning a more human-centered evolution of Industry 4.0, as they lack adequate resources, competences, and cultural mindsets. In this regard, extant literature has suggested that external actors, such as governmental institutions, universities, and research centers might assist SMEs in effectively implementing Industry 4.0. Still, the role of such actors has yet to be explored. Therefore, this study aims to empirically investigate the role of Competence Centers (CCs), which bring together the main actors within innovation ecosystems, in supporting SMEs towards a more human-centered implementation of the Industry 4.0 paradigm. By conducting a multiple case study among Italian CCs, the article contributes to the formalization of the role of CCs in assisting SMEs during the implementation of Industry 4.0 technologies, utilizing a more holistic vision.**

***Index Terms*—competence centers, human-centeredness, industry 4.0, multiple case study, SMEs**

I. INTRODUCTION

In recent years, academics and practitioners have paid increased attention to technology-oriented megatrends, such as the Industry 4.0 paradigm [1], [2]. Researchers agree that the adoption of Industry 4.0 technologies will enhance firms' productivity [2], [3], increase workers' capabilities and performance [4], and provide environment-related benefits (such as reduction of waste, improvements in energy and resource efficiency, and higher transparency of emissions) [3], which will ultimately lead to innovation in business models [1], [3], [5].

While the manufacturing industry has just begun harnessing the benefits of Industry 4.0, researchers from different fields have argued that, if the implementation of Industry 4.0 happens without considering the wider social implications, this may jeopardize human and societal well-being [6], [7], [8]. In fact, the true potential benefits of Industry 4.0 have recently been questioned and criticized for driving society toward a technologically determined scenario in which the real benefits for the larger society are compromised [9], [10], [11]. For instance, significant changes are expected in the field of work, as fewer individuals may be needed for production [12] and future production systems demand new competencies from employees [9]. Socially sensitive challenges, such as the replacement of blue-collar workers or workers' alienation, have been increasingly emphasized [4], [11], [2], as Industry 4.0 is expected to cause drastic changes in how workers perform their jobs [4]. Therefore, Industry 4.0 implies a profound transformation that may result in the need for high-level knowledge and a profound restructuring of firms' work systems [13], [14]. According to the World Economic Forum (2018), the fourth industrial revolution may cause the displacement of 75 million jobs by 2022 [15]. Therefore, firms may feel forced to innovate and maintain competitiveness by using approaches

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that take into account social issues and human-centeredness [4], [16].

The European Commission has been encouraging a technological transformation that, rather than displacing people, would encourage the inclusion of human and societal factors in a more desirable digital future [17]. Several scholars have argued that this apparent shift from a technology-oriented focus toward a more human-centered view [13] bases technological development on a more responsible approach to innovation, whose core paradigms would include respect for human values, more collaborative relationships between humans and robots, societal well-being, and higher consideration of ethical and socio-cultural factors [6], [7], [18]. Few academics and practitioners have seriously considered the possibility of a fifth industrial revolution in which the cooperation between humans and robots would become more symbiotic based on solid ethical frameworks designed according to human values (e.g. [7], [10]).

Firms, especially SMEs, face several challenges in the implementation of Industry 4.0 [19], [20]. Besides financial constraints, technical integration issues, and data security, SMEs are also challenged by a more socially sustainable evolution of Industry 4.0 (see [21]). For instance, if Industry 4.0 will be marked by increasing labor shortages, then companies will have to deal with a lack of an appropriately skilled workforce and longer times needed to train employees [9]. Overall, SMEs seem to lack the adequate resources, competences, and cultural mindsets needed to successfully implement Industry 4.0 (e.g. [22], [23]).

Socially and environmentally driven innovation processes occur in complex innovation ecosystems, in which different actors and entities coexist and exchange knowledge [24], [25], [26]. Therefore, extant research suggests that to successfully implement Industry 4.0, SMEs may need to leverage external assistance, which could be provided by governmental institutions, universities, and research centers [9], [3], [2].

To the best of our knowledge, the role of such external actors in supporting SMEs' implementation of a more socially sustainable Industry 4.0 has yet to be studied. Notably, the collaboration of the public and private sectors is pivotal in innovation ecosystems and has become central to policy makers' agendas [27]. Therefore, given the increased attention to Industry 4.0 technologies' larger impacts on work systems and society [10], this study carried out an empirical analysis of CCs, a collaborative research initiative between the private and public sectors that brings together the main actors in innovation ecosystems (i.e., university, government, and industry) [28] to support firms in implementing a more human-centered Industry 4.0. As the mission of CCs is to conduct experimental research and implement radical innovation projects via the adoption of Industry 4.0 technologies [29], this article considers the following research question: *how can CCs support SMEs in implementing a human-centered Industry 4.0?* To this end, we conducted a multiple case study analysis of six Italian CCs. The study contributes to the literature on Industry 4.0 by empirically demonstrating that CCs are assisting SMEs in the implementation of a human-centered Industry 4.0 technologies by providing firms with extensive training and opportunities for testing technologies before investing as well as crafting open calls for projects funding around societal issues. However, CCs struggle at tackling ethical questions as firms have difficulties in fully understanding the importance of ethics when implementing new technologies.

The rest of this article is structured as follows. The following section reviews the literature on the human-centered dimensions of Industry 4.0. Then, the article describes CCs as actors in the Quadruple and Quintuple Helix innovation systems. The third and fourth sections discuss the methodology employed for conducting the empirical analysis and the study findings, respectively. The last section considers the study's theoretical and managerial implications as well as its limitations and outlines some future research directions.

II. Literature review

A. Unpacking human-centeredness and the implementation of Industry 4.0

Originally introduced as a strategic initiative in Germany in 2011, Industry 4.0 describes a new maturity stage for product firms, which—by implementing technologies such as the Internet of Things, cyber-physical systems (CPS), artificial intelligence (AI), and big data—can achieve higher value for both customers and

the companies' internal processes [1]. With the fourth industrial revolution, smart, connected, and autonomous digital and physical technologies were implemented in factories, which enabled the production of high-quality smart products and services, increased production efficiency [3], [2], reduced waste, energy consumption, and emissions [5], and enhanced workers' capabilities and performance [30], [4].

Notably, Industry 4.0 technologies have been argued to disrupt traditional production and management paradigms [30] as well as work systems, including organizational structures and workers' roles and responsibilities [16]. However, it remains unclear whether the combination of technical solutions and work-system arrangements will evolve toward technocentric or anthropocentric scenarios [31]. Although new technologies could enable the allocation of human resources to higher value-added areas, some scholars have recently argued that an over-technocentric focus on the optimization of industrial production processes may overlook the broader social, political, and cultural landscapes [9].

Even the European Commission [32] has acknowledged the possibility that a new industrial revolution may involve a major shift of industrial production toward a much closer and intertwined cooperation between humans and robots. In this regard, a key concept of Industry 4.0 is Operator 4.0: a smart, skilled, and creative worker assisted by a number of technologies for improving her physical, sensorial, and cognitive capabilities (e.g., [7], [33]). Therefore, the Industry 4.0 paradigm entails the redefinition of human workers as they take on new responsibilities in collaborating with and supervising the tasks of their AI-powered machine co-workers [32], [30]. For example, Demir et al. [13] envisioned an industry focused on combining the creativity and craftsmanship of humans with the speed, productivity, and consistency of robots. Under the umbrella name of Society 5.0 (or "Super Smart Society"), similar principles of human-centeredness have also been proposed as an overall growth strategy for society as a whole [6]. The Japanese government [40] announced its intention to implement Society 5.0 as a transformative and strategically critical next stage in the development of Japanese society, which will involve "merging the physical space (real world) and cyberspace by leveraging ICT to its fullest" [34, p. 13], thereby providing "a common societal infrastructure for prosperity based on an advanced service platform" [35, p. 1]. Society 5.0 seeks to refocus innovation processes by placing societal needs at the center of an integrated approach to technological transformation for improving quality of life, social responsibility, and sustainability [36].

Although the need for a more holistic and socio-technical perspective on how Industry 4.0 may impact social, economic, and environmental systems has been widely acknowledged by researchers, policy makers, and practitioners, predictions on how it might unfold in practice have been mostly speculative [10]; [16]. Moreover, various studies from different fields have focused on a broad range of topics, from the realignment of organizational structures [31], work systems, and manufacturing processes [16], [30] to ethical, socio-cultural, and environmental issues [10]. Therefore, drawing on the extant literature on Industry 4.0, we sought to identify the most important factors associated with a human-centered implementation of Industry 4.0 technologies (see Table I below). Due to the multidisciplinarity of the topic, it was necessary to consider contributions from different bodies of knowledge.

TABLE I
FACTORS THAT LEAD TO A HUMAN-CENTERED IMPLEMENTATION OF INDUSTRY 4.0

Factors that lead to a human-centered implementation of Industry 4.0						
Societal well-being [18], [37], [13]	**Workers' well-being**				**User-centered design of manufacturing and work systems based on Industry 4.0** [16], [40]	**Ethical and responsible implementation of technology** [30]
Environmental sustainability and societal well-being	**Safety management** [16], [15] Prevent work accidents and increase health safety	**Ergonomics** [4], [16], [10], [38], [39] Physical (fatigue) Psychological (mental stress)	**Learning and training** [4], [13] Workers should be provided with adequate training and education to learn new tasks brought along by new technology	**Work-life balance** [4] Firms must consider workers' personal requirements, such as autonomy, teamwork, motivation, and accountability.	Workers need to be engaged during the restructuring of manufacturing processes so that their opinions and preferences can be taken into account and risks of dissatisfaction minimized.	Inclusion of ethical aspects and human values Provision of formalized standards, guidelines, and codes of practice for an ethical use of Industry 4.0 Provision of ethics training, an ethics-advice office for workers, and norms for translating values into design requirements

1) Societal well-being

According to Society 5.0 paradigms and the United Nations' Sustainable Development Goals, Industry 4.0 technologies should be implemented by considering production efficiency and the technologies' impacts on the broader socio-cultural context [18]. In other words, it is important that economic advancements are always balanced with actions that address social problems as well. In this way, business environments can address the needs of the broader socio-cultural context, which must be constantly monitored so that individuals' quality of life improves [41]. According to Bednar and Wench [37], Industry 4.0 initiatives must balance the needs of all the involved stakeholders, and technologies must be used for the benefit of society. For example, systematic prevention of waste, closed-loop supply chains [42], and bioeconomy may all help to achieve a balance between ecology, industry, and economy [13]. The COVID-19 pandemic has further heightened this potential, as better interaction between humans and machines may help in handling emergent medical situations by improving the detection and analysis of diseases and generally enhancing the performance of treatments [43], [44].

2) Workers' well-being

Kadir and Broberg [45] argued that the introduction of Industry 4.0 technologies must consider workers' well-being and needs. When manufacturing systems can meet the needs of current and future employees, such systems can then be considered human-centered [46]. Pinzone et al. [4] argued that workers' well-being should be assessed using the following four aspects: safety management, ergonomics, learning and training, and work-life balance.

a. Safety management is assessed via the analysis of procedures aimed at preventing work accidents and

increasing workers' safety. As closer human-machine collaboration may evoke safety concerns, firms should also implement additional technologies, such as collaborative robots, digital twins, hands-free gesture control, and caregiver functionality, to further in-crease physical and mental safety [16], [4].

b. Ergonomics is a scientific discipline aimed at understanding the interactions between humans and other system elements in order to optimize human well-being [47]. In the Industry 4.0 context, ergonomics is usually assessed via the analysis of the working environment (machines, tools, products, places) in terms of how well this environment takes into ac-count humans' physical (physical stress related to operator movements), psychological (mental workload), and physiological characteristics [16], [4]. In terms of physical elements, collaborative systems should aim at reducing human fatigue and the difficulty of tasks [10], [11]. In terms of psychological aspects, augmented-reality devices can be used to reduce mental stress [38], [39], while sharing data on workers' stress levels across departments may improve cognitive ergonomics [16].
c. Learning and training are assessed via the analysis of the support levels provided to workers for learning new tasks and methodologies [4]. As the automation that Industry 4.0 entails may have unexpected effects on jobs, it is necessary to enhance workers' learning capabilities so that workers can quickly adapt to a sudden change in tasks [13].
d. Work-life balance is assessed via the analysis of how a firm approaches workers' personal requirement, such as schedule, flexibility, autonomy, teamwork, motivation, and accountability [4].

3) User-centered design of manufacturing and work systems based on Industry 4.0

User-centered design places individuals along with their preferences and values at the center of innovation processes [48], [8]. As the introduction of Industry 4.0 technologies into established manufacturing processes may cause the disruption of workers' tasks and routines, along with a complete restructuring of how operations are organized, it is important to engage workers during the implementation process for their opinions and preferences to be heard and considered [16]. In addition, workers should also be observed while performing their tasks using their new technology so that its usability comfort and intuitiveness could be better understood [40]. In general, manufacturing and work systems should be redesigned taking into account how the technology might impact workers' well-being—for example, how workers feel about a potential division of tasks between them and robots [16].

4) Ethical and responsible implementation of technology

Although digital technologies have the potential to enhance workers' capabilities, such technologies also pose a number of ethical issues, such as human–robot competition [10], [37], shrinking human workforce, and unemployment fears [13]. If poorly implemented, misused, or abused, Industry 4.0 technologies can, indeed, violate human values and cause harm to workers [49], [10]. According to Longo et al. [10], the observed workers' resistance to Industry 4.0 can be considered a sign that workers' values are not respected. Broadly speaking, an ethical implementation of technology involves a strict adherence to formalized guidelines, standardized codes of practice, and legal frameworks regarding the ethical use of Industry 4.0 technologies. Furthermore, a general socio-cultural sensibilization regarding these topics should be fostered through the provision of ethics training, seminars, and the creation of ethical advice offices and officials [10].

B. Competence Centers as actors in the Quadruple and Quintuple Helix innovation systems

In general, extant literature suggests that firms, especially SMEs, may obtain the competencies and resources needed for coping with the challenges posed by Industry 4.0 by leveraging external support from partners or experts [9], [3], [2]. Such collaborations may become even more necessary if Industry 4.0 is to

include human-centered factors, such as social sustainability [50]. In this regard, Ferreira et al. [6] have suggested that a successful implementation of the Industry 4.0 paradigm requires active collaboration among governmental agencies, universities, and businesses. Therefore, innovation ecosystems are pivotal for the diffusion of Industry 4.0 technologies and for supporting firms in the effective implementation of such technologies [24].

These kinds of collaborations have been theorized in the Triple Helix model of knowledge developed by Etzkowitz and Leydesdorff [51], according to which the interconnections between academia/university, industry, and state/government are at the basis of national innovation systems. The rise of such collaborations indicates the transition toward joint approaches to innovation creation and diffusion [25]. More specifically, innovation ecosystems are characterized by the following actors: the university as the main creator of knowledge; the firm, which produces innovation by improving organizational processes and product commercialization; and the government, which finances and provides political support to the development of science-based technologies. Interestingly, Carayannis et al. [26] introduced the Quintuple Helix model, which embeds innovation actors in a culture-based system that includes society as well as the natural environment of society and economy. According to Carayannis and Campbell [28], in advanced knowledge societies, knowledge production and innovation require that social actors become embedded in the innovation ecosystem as users of innovations, while the environment provides the framework in which innovation functions as a solution to environmental challenges and enables more sustainable development.

Ever since European countries have acknowledged the importance of collaboration between the public and private sectors for facilitating knowledge transfer and innovation, innovation ecosystems have become central in policy makers' agendas [27]. In this context, CCs stand out as innovation ecosystems that are composed of various actors, namely governments, researchers, and industries, and are purposefully established to assist SMEs in the implementation of Industry 4.0 technologies.

To promote SMEs' growth and innovation, in 2016, the Italian government established the national plan *Industria 4.0*, with CCs being conceived and launched as hubs "of innovation constituted, according to the model of public-private partnership, as defined in letter b), by at least one research organization and one or more enterprises. The number of public partners may not exceed 50% of the total number of partners." CCs are considered to be high-level training centers mainly focused on industrial and experimental research.

Consequently, it is important to understand how CCs, conceived as a new innovation ecosystem composed of different actors, assist SMEs in envisioning and implementing a human-centered Industry 4.0. Our position is further validated by the fact that, despite the increasing relevance of external actors for the implementation of the human-centered Industry 4.0, their role remains under investigated.

III. Methodology

A. Research design

We employed a qualitative methodology to perform an exploratory analysis, as a sufficient systematic investigation of CCs' role in the context of human-centered Industry 4.0 has not been conducted. The multiple case studies approach is particularly suited to this task because it emphasizes the richness of the context in which the phenomenon of interest occurs, and the findings are deeply grounded in the varied empirical evidence collected for each case [52], [53]. Case studies are particularly useful because they provide in-depth information to answer "how" and "why" research questions and enable a holistic, comprehensive, and realistic understanding of the studied phenomenon [54]. As we investigated how Italian CCs assist SMEs in the implementation of a human-centered Industry 4.0 by uncovering the actual meanings that CCs give to human-centeredness and the current practices for implementing this concept, the multiple case study methodology was particularly suitable, as it provided us with various opportunities for discovering CCs' and SMEs' practical experiences as well as potential issues (see [55]). CCs are led by universities or research centers and involve a number of private partners, who finance half of the project investment [56]. Although all CCs'

programs support SMEs in a structurally similar way—that is, via orientation and consulting, training, and experimental development projects—such programs are subject to local adaptations, and each CC is specialized in a specific set of competences related to Industry 4.0 [29].

Therefore, as suggested by Eisenhardt and Graebner [53], our study adopted a theoretical sampling approach and examined six case studies, each based on a different CC. Such contextual variety is recommended for theory building, as it can provide greater reliability, less dependency on a particular context, and better generalizability of the findings [57], [54].

B. Data collection and analysis

For each case study, the primary source of empirical data consisted of semi-structured interviews with CCs' key informants and with the representatives of the CC's partner and customer companies, whenever possible. The key informants were the Competence Center's General Managers, as they possessed a more comprehensive view of the studied phenomenon. Moreover, we also interviewed node managers, executive researchers, and development managers whenever they were willing to participate in the interviews.

Semi-structured interviews suited the study's exploratory approach because such interviews maintain a structured approach while also leaving space for openness; consequently, investigators must provide sufficient space for interviewees to disclose their experiences, opinions, and knowledge [54]. The involvement of multiple respondents and investigators in each CC enhanced the validity of our findings [54]. Interviews lasted between 40 and 60 minutes, were audio recorded and transcribed verbatim. The interview script was carefully designed based on the previously analyzed literature. More specifically, based on the four central factors that lead to a human-centered implementation of Industry 4.0, we developed two different semi-structured interview guidelines, one for CCs and one for partner or customer companies. Overall, the purpose of the interviews was to identify the following information for each factor: opinions, current and future practices, and the associated challenges (see Appendix 1).

The questions were carefully designed to be unobtrusive and nondirective to avoid the potential pitfalls of "active listening" (see [58, p. 21]). Although we used a common set of questions, the interviewees could elaborate and expand on their answers, which allowed researchers to ask additional probing questions [59]. After a preliminary analysis, the data collected during the interviews were supplemented with additional details via further email communications with the respondents meant to clarify the responses and address missing information.

The interviews were also complemented with additional publicly available data from the internet and with official data provided by CCs (e.g. CCs' open calls for projects funding and descriptions of the funded projects, the training courses offered by CCs, etc.) [60], [54]. Document data analysis helped us gain a full understanding of the CCs and their core focus; such data also enabled us to identify explicit references to matters of human-centeredness in the CCs' written official material. These data were used to complete the overall description of each case study [54] (see Appendix 2 for a summary).

All the collected data (i.e., the interview transcripts and additional documentation) were entered into NVivo12 software for manual coding and were analyzed using thematic content analysis [59]. More specifically, we followed Gioia et al.'s [59] approach from the empirical to the conceptual, which focuses on the identification of emergent themes that match the literature to facilitate theory building. As the purpose of the study was to understand an emerging and relatively new phenomenon, data were inductively coded so that related concepts could be merged into more abstract themes [61]. In fact, inductive coding is recommended when the overall research context has not been studied sufficiently and when the aim of the study is not theory testing but theory building [53]. Accordingly, the data were first coded via open coding, which maintains the integrity of informant-centric concepts. During the second-order analysis, axial coding was used to identify the similarities and differences among the codes identified during the first-order analysis. Then, the researchers further abstracted the axial codes by systematically combining the insights from the cases with the extant literature [62].

Appendix 3 provides a sample of the coding process for the aggregate theme "Education and training to overcome SMEs' barriers to the formation of a holistic vision of Industry 4.0." The theme discusses how both SMEs and CCs acknowledged the importance of education and training as the first concrete step toward human-centeredness and incorporates second-order themes, such as "Education for sensibilization regarding social sustainability and human-centeredness" and "Education and training for overcoming entrepreneurs' negative attitudes toward Industry 4.0 technologies." The second-order theme "Education for sensibilization regarding social sustainability and human-centeredness" incorporates the first-order concepts showing that for CCs and SMEs, education was the most important means by which CCs could promote human-centeredness.

IV. FINDINGS

The data analysis mainly consisted of a cross-case analysis; however, we also created a within-case analysis summary table. The table's purpose was to familiarize with each case and to keep the collected data separate. The table shows each CC's structure, general mission, key area of expertise, and key competences related to human-centeredness (see Table II below).

This preliminary step served as a basis for carrying out a more fine-grained cross-case analysis to identify, using the extant theory, recurring patterns across all the studied cases. Such replication logic is central to theory building [84]. The coding process led to the identification of five themes, which represent the main key findings of the multiple case study analysis.

TABLE II
WITHIN CASE ANALYSIS

Competence center (CC)	**Key actors**	**Mission**	**Key area of expertise**	**Competences and services related to human-centeredness[a]**
CC1	13 research organizations (universities and research centers) 94 companies 17 foundations / third-sector entities / non-profit companies	Providing partners and industry actors (especially SMEs) with dedicated technologies and services in the 4.0 domain	Advanced Robotics and 4.0 digital Technologies & Systems	Collaborative robotics Customized industrial robotics Workers' safety in the workplace (e.g., smart glasses for preventing accidents; autonomous robotics for hostile environments, etc.) Workers' skill enhancement (e.g., training with virtual reality) Smart monitoring and control of industrial processes (e.g., simulation with a digital twin) Sustainable mobility for smart cities
CC2	8 universities 4 public institutions 30 companies	Leading companies' digital transformations at a technological, strategic, social, and environmental level by balancing the digital-first approach with the human-centered approach	Social, Mobile, Analytics, Big Data, Cloud, the Internet of Things	Collaborative robotics Workers' safety in the workplace (e.g., operator tracking for safety reasons) Workers' skill enhancement (e.g., self-learning,

				adaptive digital twin, etc.) Social inclusion in the food manufacturing industry (e.g., the inclusion of workers who play a marginal role in employment)
				Services for the circular economy in the food industry
CC3	4 universities 1 public institution 39 companies	Providing a wide range of knowledge types, methodologies, and digital tools for companies' digital transformation processes	Industry 4.0 live demos	Collaborative robotics Workers' skill enhancement (e.g., intelligent worker assistance systems) Smart monitoring and control of industrial processes (e.g., simulation with a digital twin) Services for the circular economy Smart energy for reducing energy waste
CC4	2 universities 23 large companies	Providing strategic and operational support to manufacturing-oriented firms in the digital transformation of industrial processes	Additive Manufacturing and Digital Factory	Collaborative robotics Workers' well-being (e.g., metrics specifically developed for measuring workers' health and well-being) Workers' safety (e.g., smart watches for workers' security) Smart energy for reducing energy waste (e.g., smart grid, smart meters, etc.)
CC5	6 public institutions 33 companies	Developing strategic infrastructures' security via Industry 4.0	Security and optimization of strategic infrastructures	Workers' skill enhancement (e.g., smart training via augmented reality) Workers' well-being (e.g., automation of tasks and analysis of workers' vital parameters via wearables)
				Workers' safety (e.g., monitoring security of CPS)

				Security and maintenance, infrastructure monitoring via drones and digital twins to prevent and manage dangerous events
				Smart mobility for smart cities
CC6	5 universities 7 public institutions 45 companies	Supporting companies' digitization and innovation processes in relation to Industry 4.0 technologies and facilitating technology transfer and the exchange of "best practices"	Big data innovation and Additive Manufacturing	Collaborative robotics Smart monitoring and control of industrial processes (e.g., simulation with a digital twin) Big data for sustainability (e.g., developing predictive models in precision medicine) Services for smart cities, the circular economy, and sustainable applications

[a] The CC's competencies and services tend to be related to concrete cases of successfully implemented innovations by the companies that make up the CC itself. Therefore, these cases are not directly related to the projects successfully funded by the CC but refer to the skills, abilities, and services that a hypothetical customer company could find in the CC. Some significant examples of the competences related to human-centeredness are reported in the table.

A. Education and training for overcoming SMEs' barriers to the formation of a holistic vision of Industry 4.0

All six CCs emphasized that SMEs often have little knowledge of the key benefits and drawbacks of Industry 4.0 and approach CCs with vague ideas regarding the impacts that Industry 4.0 technologies may have on the organizations. CCs' partner companies further supported this point by highlighting that often firms have little understanding of Industry 4.0. In addition, financial difficulties, a working environment characterized by workers' digital divide, and a focus on daily routines further hinder the formation of a more holistic understanding and appreciation of Industry 4.0, including its human-centeredness.

> CC3 General Manager: "Since they have never seen a 4.0 factory, they do not know that this world exists, and therefore they do not approach it. [...] Their difficulty is very much related to a question of understanding technologies."

> CC1 Partner: "As of today, firms still lack an attitude toward Industry 4.0 that would allow them to see the opportunities it might lead to. We recently had the chance to develop polystyrene calenders for one of our clients. Although we could have adopted an Industry 4.0 approach through a collaborative arm, in the end, the client opted for a more standard approach with conveyor belts. [...] The problem is that entrepreneurs are not aware of these new digital technologies, and requests are rather sporadic."

Accordingly, CCs felt compelled to improve SMEs' interest in Industry 4.0. By increasing firms' awareness and sensibilization, CCs also attempted to gradually shift technology implementation away from a top-down approach, mostly driven by financial measures and incentives, toward a more holistic approach that also considers workers' well-being and skill enhancement.

CC5 General Manager: “The risk is related to a top-down approach in which we say, ‘The future lies in these technologies, use them, introduce them in the company,’ a very strong financial leverage and total absence of work on people. This does not give the desired outcomes. The central element for a true development of 4.0 technologies is the person.”

CCs univocally asserted that a purely technocentric vision of Industry 4.0 may lead to common misconceptions regarding these technologies’ negative social impacts. Education was said to be the only way through which such unfavorable perceptions could be modified. If the implementation of technologies were anticipated by training and education, workers would be able to acquire the knowledge and skills that would lead to a favorable working environment and thus an acceptance of the technology. According to CCs, lack of knowledge and work-system preparation often leads to implementation failures.

CC2 General Manager: “The central element of Industry 4.0 is the individual. Therefore, if the technology must be properly used and understood, its users’ awareness is vital. Working on individuals becomes mandatory to make sure that they feel reassured. That’s why we work first with people and then with technology.”

CC4 General Manager: “Training is anticipation. We are often found to chase investments with training, but it should be the other way around. First training, and then the implementation of new technologies.”

The findings confirmed that, via several means (orientation, consultancy, workshops, seminars, webinars, YouTube videos, and customized hands-on training activities aimed at familiarizing individuals with Industry 4.0), CCs help SMEs to attain a general awareness of and cultural sensitivity toward broader social sustainability issues. Webinars, workshops, and other events usually achieve this aim because they are open to the broader public; moreover, although their primary goal is to develop individuals’ awareness and knowledge of Industry 4.0 technologies, at times, the aforementioned measures also address more human-centered topics, such as collaborative robotics, workers’ well-being, the circular economy, and the like. CCs also offer more long-term courses whose aim is to upskill or reskill both the workforce and the managerial class. In fact, according to CCs, the underestimation of the im-portance of upskilling and reskilling workers is one of the most important issues that firms face today. CCs’ customers also suggested that CCs’ training and education courses help meet workers’ training needs.

CC2 General Manager: “I would say that training is the key aspect. If training has these [human-centered] issues and they are included in our education programs, such as webinars, courses, and anything else, it is obvious that it helps to proceed in this direction. For example, at the end of this week, we will have a webinar on the circular economy.”

CC3 customer: “We think the training proposal is valuable and customized to our needs. We opted for a training program with two different aims. The first training course will be an introduction to Industry 4.0 technology but also focused on research and development. This course will be directed at the technical office. A second training course will focus on maintenance and Internet of Things sensors. This course will be directed at department heads and maintenance managers.”

Therefore, although CCs’ training and education may vary in terms of the course types offered and the topics addressed, to a certain extent, all training efforts support human-centeredness via educational practices

and, overall, generate more favorable working environments and increase cultural sensitivity to certain critical topics.

B. "Test before you invest" for raising SMEs' interest in user-centered manufacturing systems and operations

A key aspect of all the analyzed CCs was that they functioned as intermediaries between SMEs and technology providers. This is important because the findings revealed that, although SMEs may have been aware of what competences they needed and may have shown willingness to invest in new technologies, they often did not know how to acquire the needed competencies. In fact, the distance between firms and competence providers is often so wide that a firm, on its own, would hardly be capable of finding the right providers without mediation.

> CC1 General Manager: "The Competence Center provides SMEs with the competences they need. SMEs know what competences they need but not where to find them because they are completely disconnected from the industry that provides these solutions."

> CC3 Customer: "We are challenged in finding the right partners that would provide us with the best technological solution. This is another reason why we turned to the Competence Center. For instance, we decided to in-vest in RFID technology a long time ago, yet when trying to understand who could help us, we felt lost."

> CC4 Partner. "Our product has been conceived to provide a close interaction between the technology itself and the operator. The Competence Center understood its potential and has been able to put us in touch with firms interested in this specific technology."

Besides a solid network of technology providers, which allows to efficiently pair up a firm's needs with the right competence provider, all the analyzed CCs also provided firms with the opportunity to test the technologies before making the investment. Due to having their physical locations equipped with "pilot lines" or "live demos," CCs enabled firms to see the technologies "in action" and to test them using their own materials and workers. Such "test before you invest" logic allows firms to evaluate and compare different options.

> CC2 General Manager: "We provide firms with live demos to show how those digital technologies work in practice. The Competence Center has industrial plants for food crafting and packaging, for steel engineering, where we effectively employ 4.0 technologies. The idea is being able to show how technologies, such as exoskeletons, automated guided trucks, can help workers to be fully productive."

> CC4 General Manager: "We provide firms with pilot lines, one devoted to 3D printing, another focused on digital cobots, an area to test ergonomic solutions to guarantee safety in the workplace. We also offer a metric developed with a university to measure work's cognitive and physical impact on human's health and well-being."

> In general, CCs' customers appreciated such possibilities, as expressed by one company:

> CC3 customer: "The Competence Center provides a small digital factory for testing technologies, which is an advantage for us. Those who have not had the chance to visit more structured companies from an Industry 4.0 perspective can see the real application of the technologies, which is a tremendous opportunity."

The findings showed that initially, companies are interested in improving their economic performance via small investments in a new technology. Such initial investment is usually the first step on an innovation path for increasing interest and investments. CCs strove to encourage more radical innovations for redesigning and enhancing firms' business processes and activities rather than focusing on the introduction of individual technologies.

> CC4 General Manager: "We usually start with a business redefinition since it would be trivial to help with a single technology. An example of 3D printing: if the company approaches 3D printing, the company must first redefine its assets, its way of working, and its business model. We start right from there, even before doing any experimentation, we highlight disadvantages, advantages, opportunities, etc."

> CC3 General Manager: "It is not just a matter of technology adoption, in terms of buying and installing a machine; it is a matter of reviewing skills and developing a different way of managing the factory and the company, much more based on data. The challenge is not buying the machine for using fiscal incentives. The challenge is learning to use, to read, to exploit the data that the machine provides to improve its performance."

Although CCs encouraged a structured full redesign of firms' internal processes and operations, they were not implemented according to consistent processes and standardized guidelines, which would have ensured a uniform approach to human-centeredness. Furthermore, elements such as employees' involvement in the design phase, technology integration with work systems, and workforce disruption were generally considered to be of secondary importance compared to economic or financial performance.

CCs agreed that SMEs, when investing in a new technology, are mostly interested in costs/benefits or fiscal incentives. These priorities make them overlook the fact that, if technologies are introduced without first creating organizational acceptance, the implementation may have a minor beneficial impact.

> CC3 General Managers: "We worked with a firm whose new director asked for our assistance as they wanted to redesign the factory, reducing the number of working stations down to seven so that each operator's work would increase and would be more varied. Once the project was presented to the labor unions, the workers raised concerns regarding reduced privacy and reduced social interaction, even though they would also have received a salary increase. The lesson that I have learned from that is this: Are we sure that we all have the same standards when talking about work alienation and that some people may prefer less qualifying tasks in our perspective as researchers?"

CC3 case showed that designing solutions with a technocentric rather than a user-centered approach, with minimal involvement from the workers and limited considerations regarding the socio-technical aspects of work systems, may cause organizational frictions in the initial phase of the implementation. This could cause workers to lose motivation or lower their moral potential, thus leading to poorer performances. In this regard, CCs' partners have emphasized that involving operators in developing the most suitable technological solutions, which address workers' personal requirements, is becoming increasingly important to prevent resistance and ensure the effective implementation of Industry 4.0 technologies.

> CC6 Partner: "When introducing new technologies, involving the operators who conduct the fieldwork in this process of change is pivotal. Workers should be listened to as they can provide a much greater contribution to co-design the solution that is more suitable for them—together with the technology provider—as they know their needs best."

C. Human-centeredness as workers' safety and physical well-being

All the CCs envisioned human-centeredness as intrinsically embedded in the 4.0 technologies in which they specialized. For example, CC1 has developed several artificial intelligence and virtual reality solutions for increasing workers' safety during training as well as devices for monitoring workers' health in hostile environments. Safety is also encouraged via open call requirements. In this way, firms are "forced" to address safety issues, either as the central project objective or by having to comply with specific call requirements, which award premium points to projects with positive externalities on workers' health and safety according to the principle "prevention through design." Safety was the core competence area of CC5, whose focus included not just workers' safety but also the safety of goods transportation and people's security (e.g. passengers, visitors) in relation to infrastructures.

> CC5 General Manager: "Infrastructures have, indeed, some critical peculiarities in terms of workers' security. Their management involves complex and risky processes, and they face a number of dramatic issues. We are currently developing a digital twin for Genova's port, which can assist in accident prevention, traffic congestions, port inefficiencies, and so on."

Ergonomics emerged as another key innovation area, and the CCs had developed a number of relevant innovations, such as exoskeletons, for monitoring workers' health parameters so that tasks could be adapted and physical stress reduced.

> CC4 General Manager: "The ergonomics of a working environment are extremely important. Task redefinitions need to be tested and accepted by workers first. For example, when maintainers are faced with remote control devices, they might initially show reluctance. It is very important that devices are introduced to workers with ergonomics studies which confirm their safeness. Besides, if they raise problems, like, for example, that smart glasses give them a headache after 30 minutes of use, tasks need to be redefined taking the raised issues into account. And this is how we help."

If, on the one hand, CCs consider workers' safety and physical well-being to be key priorities of Industry 4.0, then, on the other hand, they seem to neglect psychological and emotional well-being. In fact, for CCs, human-centeredness meant the following: augmentation of human capacities, ease of use, safety, etc. Only CC1 mentioned psychological aspects, such as mental stress, fears of new technologies, personal problems, privacy, and accountability, as equally important. In fact, three CCs perceived downsizing risks or motivation loss caused by automation as inevitable outcomes.

> CC1 General Manager: "Often, we deal with entrepreneurs whose main goal is to preserve a healthy future for their firm. Only by doing this they can guarantee work to their employees. For example, we worked with a big multinational firm which, for many years, has been at risk of closing down. However, thanks to the implementation of advanced robotics and automation, they have successfully managed to keep their Italian site and provide jobs to hundreds of white-collar workers. In order to not close down, they had to make choices which did not receive the approval of labor unions and received negative critiques by the public. Having said that, what would have been better? As an entrepreneur, I need to keep the business running long term."

> CC3 General Manager: "What sort of privacy should there be when you are working for a firm? In 1950, I was supposed to stamp a card when I was arriving and leaving work, plus, at the end of the day, they would count the number of pieces I had made. Wasn't this the same thing? Working breaks are regulated by labor unions; if you are hiding, you are trying to be smart [...] The privacy concept in working environments is a big nonsense."

These findings suggest that, in practice, all six CCs supported the implementation of human-centeredness through the provision of technologies that do not replace but augment workers' capacity, increase safety, and improve physical well-being. However, CCs seem to neglect other equally important human-centeredness aspects, such as those related to psychological and emotional issues.

D. The myth of open calls for projects funding for societal well-being: "Ticking a box"

Open calls for projects funding play an important role in SMEs' transition toward a human-centered Industry 4.0 implementation. First, open calls present lists of thematic areas that may lead companies to propose and implement innovative projects aimed at improving workers' health and safety, ergo-nomics, environmental sustainability, etc. Second, project proposals are usually assessed via a number of ordinary and excellence criteria that include human-centered issues, such as a project's impact on social sustainability in relation to workers, society, and the environment.

> CC1 General Manager: "So, through the design of open calls that lead precisely in these directions, we can succeed in influencing companies. [...] In this way, with our open call, we force the company to look beyond. [...] Therefore, within our calls, we assign higher scores based on these issues [such as environmental sustainability and workers' well-being and safety]."

> CC3 General Manager: "So, regarding the criteria we use, certainly sustainability is a criterion, but not all projects have an ultimate goal which is sustainability or human-centeredness. Yet, in the last call, for example, we assigned five points out of 100 if the topic of health and safety was the subject of the proposal."

> CC1 Partner: "The Competence Center also issued an open call during the pandemic which encouraged companies to submit projects aimed at implementing technologies for increasing workers' safety."

However, CC2 and CC3 strongly emphasized that open calls are just one CC activity and need to be complemented with efforts to identify and provide the right technology for each company. In fact, pre-established criteria that address human-centered issues were perceived as mere compliance with Euro-pean standards, a formality that is easy to overcome by using pre-packaged sentences that allow firms to "tick the box." CCs' true value was said to lie in their training and consultancy services.

> CC2 General Manager: "We have borrowed the European forms, those for the SMEs' instruments, and, therefore, it is also required to have an impact from a social and environmental point of view. The calls also take this into consideration in the evaluation criteria we have borrowed. So, in addition to the form, also the evaluation criteria are those of the European call. We have adapted to the best practices in this sense."

> CC3 General Manager: "Open calls are only one of the activities of Competence Centers. Someone considers Competence Centers as if they were a shop for open calls. [...] This is not the way to create a culture of sustainability or human-centeredness. If our goal is to help people, the most effective way is to train, seminars and conferences."

E. The long way toward human-centeredness"

All six CCs strongly believed that the potential of Industry 4.0 goes well beyond production efficiency and enables new approaches to solving the current social challenges (e.g., social inclusion of workers, workers'

replacement) and environmental problems. According to CC1 Node Manager, innovation re-search has recently shifted from developing technologies aimed at improving production efficiency toward developing technologies that consider workers' well-being:

> CC3 General Manager: "The first mistake is to think that Industry 4.0 is aimed only at the efficiency of the factory and [that] it is a technological rather than a cultural or social revolution, I do not agree with this vision. All industrial and technological revolutions have always included a socio-cultural revolution."

> CC2 General Manager: "Technologies also allow new approaches to the current social/cultural issues, like, for example, the working capacity of disabled people or other marginalized categories."

> CC4 Partner: "Let's say an important challenge is seeking to understand how introducing Industry 4.0 technologies might create jobs by reskilling, and not by replacing, people. We took part in such a process within the automotive industry, where the introduction of a new technology, at first, seemed intended to replace two operators, whereas the real aim is to safeguard humans by enhancing their skills and capabilities through digital technologies."

Regardless of CCs' activities (i.e. orientation, training and education, and technology transfer) aimed at making SMEs aware of the fact that Industry 4.0 means placing human and societal well-being at the forefront, more advanced issues, such as ethical matters, have not been sufficiently addressed yet. As highlighted by one CC customer, finding an equilibrium between technological, sociological and ethical matters remains the most important roadblock for both companies and CCs. Indeed, the absence of determination to tackle ethical issues means that such issues are largely neglected in practice.

Although the majority of the CCs considered ethics to be of utmost importance, they stressed that these issues are difficult to discuss, especially with small firms. Therefore, CCs predominantly dealt with this matter through education and research. On the operative side, ethics still remains too difficult to implement, as the audience has not yet reached an adequate level of understanding to be sufficiently responsive.

> CC4 General Manager: "Ethics must be addressed, but the scope is so vast that decades will pass before such issues can be fully grasped. Italy is lagging behind in terms of protocols and regulation aspects, there are several issues that are currently not addressed, including robots' responsibility, cybersecurity, and so on. Everyone is worried about robots replacing humans, but it will take 30 years and more before that, and there is time to act on the regulation in the meantime."

> CC5 customer: "The right balance between technology and humans, sociology, ethics should be found. This is the greatest challenge, and it is not so obvious that a company can find people who are open-minded enough to think about these matters. [...] Ethics is a major weakness for both Competence Centers and companies, as there is widespread resistance, and perhaps the right attitude to actually address certain topics is still missing."

In addition, CCs were further challenged by a lack of clear guidelines and standard procedures for embedding ethical principles into the implementation of digital technologies. In this regard, CCs, although at different levels, were working in this direction. For instance, the CC1 General Manager mentioned that one of their partners was a research center on robot-ethics, bioethics, and human-robot interaction. The center focuses on developing a philosophical framework through which AI can be developed by establishing a balance between technology, regulations, and ethical principles.

> CC1 General Manager: "Regarding ethics, at the moment, we are not taking any action. In the near future, we would like to generate more awareness and sensibilization toward these topics. The topic is likely to become more and more relevant, especially considering that, next year, the CC might become part of a

European network of digital innovation hubs. We have a working group which follows the themes of robotics from the point of view of ethics."

To conclude, it can be argued that all the studied CCs exhibited a generally adequate understanding of the major principles of a human-centered vision of Industry 4.0. In practice, they performed a range of sensibilization activities as well as more operative actions; together, these two types of activities can nudge SMEs in the right direction. Nonetheless, CCs also univocally recognized that more can be done in the future, especially in terms of ethical matters, given CCs' imminent evolution within the European context. Fig. 1 shows CCs' main practices according to the findings.

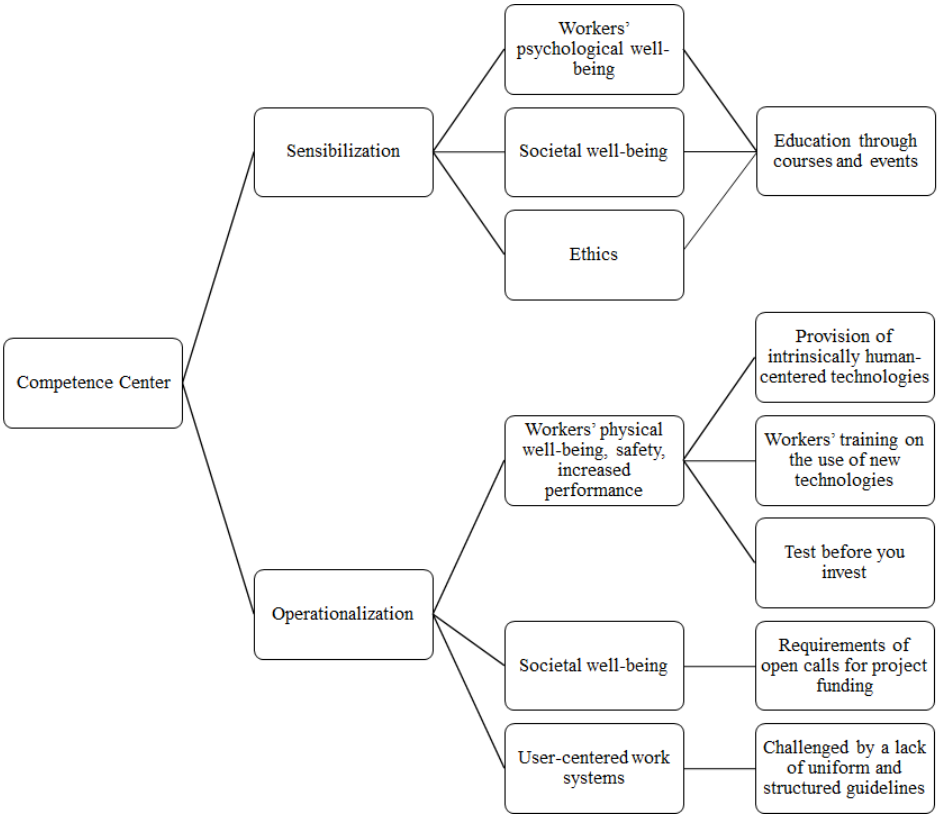

Fig. 1. The role of Competence Centers

V. Discussion

A. Theoretical implications

This article has explored how CCs assist SMEs in implementing Industry 4.0 technology in a more human-centered manner. This topic is relevant because of two main ongoing phenomena: the need for a new vision of Industry 4.0 that would be more holistic and human-centered (see [13], [6], [10]) and the emergence of innovation ecosystems, such as CCs, that support SMEs' innovations by providing competences related to Industry 4.0 technologies.

Consequently, the article offers a twofold contribution to the literature on Industry 4.0 and human-centeredness. First, by drawing on different fields of research, we have shown that a firm can be said to embrace a more human-centered vision of Industry 4.0 when, during implementation, the firm takes into account the following four factors: (1) societal well-being, (2) workers' well-being (safety, physical stress, mental stress), (3) user-centered design of manufacturing and work systems, and (4) ethical and responsible implementation of technology. This contribution is important because, so far, the existing literature on the topic has been largely speculative.

Despite the diversity of research fields, the present article has presented a more holistic and socio-technical vision of Industry 4.0 by tracing the common thread that underlies the various studies: namely, how a shift to Industry 4.0 affects human work, work systems, and society at large. Second, although previous studies have strongly emphasized the role of external actors, such as governmental institutions, universities, and research centers, in supporting SMEs' effective implementation of Industry 4.0 (e.g., [3], [2]), this role has not been studied yet. Therefore, our major theoretical contribution consists of providing empirical evidence on how CCs, a collaborative research initiative between private and public actors in innovation ecosystems, direct SMEs' Industry 4.0 implementation in a more human-centered manner.

By employing a multiple case study analysis, we have shown that CCs do, indeed, play an important role in guiding SMEs toward a more human-centered vision of Industry 4.0. More specifically, CCs actively educate SMEs' employees and managers regarding Industry 4.0 technologies by means of a wide range of educational and training programs that address human-centered issues, such as collaborative robotics, workers' well-being, and the circular economy, and by providing firms with the opportunity to test the technologies using live demos and pilot lines. The CCs' purpose is to reduce firms' hesitation in relation to Industry 4.0; once firms are familiar with the technology, CCs accompany SMEs in a gradual transformation of their manufacturing operations by introducing one technology at a time. Moreover, CCs also acknowledge the strategic importance of workers' well-being. For CCs, well-being is related to workers' safety, physical stress, and performance efficiency. In this regard, CCs are equipped with a number of technologies for boosting workers' performance, making their tasks less tiring or strenuous, providing a safer working environment, and, overall, improving working conditions.

Nonetheless, firms and CCs do not attribute the same importance to the psychological and emotional elements associated with workers' well-being (mental stress, motivation, accountability, etc.) (see [38], [39], [16]). In fact, the findings suggest that psychological and emotional elements are mostly addressed by CCs at an educational level but often forgotten by SMEs during the adoption of Industry 4.0 technologies. In terms of redesigning user-centered work systems through worker engagement by considering workers' opinions and preferences [16], the findings revealed that CCs see this as a rather challenging task because, currently, there are no uniform and structured guidelines for firms restructuring processes. CCs do try to adopt a structured and consistent approach to assist firms, always beginning with workers' education; however, the reality is that workers' engagement is usually decided by the management on a case-by-case basis. Therefore, the level and type of workers' involvement may vary considerably across SMEs. In addition, CCs also have to deal with entrepreneurs who are still attached to the technocentric approach to innovation, which rarely embraces the cultural sensitivity required for understanding the importance of workers' engagement. This often leads to workers' dissatisfaction and loss of motivation [10].

In terms of societal well-being, the findings revealed that CCs approach societal well-being at two levels: (1) education and training for generating awareness and sensibilization and (2) open calls for project proposals whose requirements include a broad range of societal well-being criteria. Furthermore, CCs extend their operational reach to include the broader society—for example, when dealing with infrastructure safety. Therefore, it can be argued that CCs play a role in improving societal well-being.

Finally, in relation to ethics, CCs acknowledge the relevance of ethics and the increasing importance that ethics is likely to assume in the near future. CCs also recognize that, at the moment, they have very little margin for action on this front. This is due to a plethora of SMEs that are still not ready to appreciate the value of ethics, as companies are very much focused on economic performance. In addition, there are few legal frameworks or uniform codes for how ethics should be put into practice.

To conclude, it is clear that CCs play a major role in assisting SMEs' transition toward a human-centered Industry 4.0 via the identified dimensions, which have different levels of impact. CCs provide crucial support in raising cultural sensitivity and improving SMEs' knowledge of the social side of production (see [49], [4]). At the operational level, CCs mostly focus on the following aspects: (1) augmenting workers' capacity,

safety, and physical well-being; and (2) encouraging new projects to consider societal well-being either as a central or a peripheral element.

In terms of user-centered work systems and ethics, the CCs' role is more challenging, as CCs operate in a socio-cultural, economic, and legal context that still has not entirely grasped the increasing relevance that ethical issues are likely to assume in the near future.

From a more theoretical perspective, the article contributes to the formalization of CCs' role in assisting SMEs with the implementation of Industry 4.0 technologies in line with a more holistic vision of Industry 4.0. This is a relevant contribution, given the increasing importance assumed by innovation ecosystems, such as CCs, and the limited empirical evidence available in the extant literature.

B. Managerial implications

This article offers insights for firms, CCs, and policy makers. On the firm side, the study has confirmed that SMEs are still struggling to implement Industry 4.0 in a human-centered way, as SMEs continue to adopt an overly technocentric approach regarding the introduction of new digital technologies in factories. In this regard, cultural aspects emerged as major barrier due to SMEs' lack of knowledge and understanding of the impacts that Industry 4.0 technologies may have on human and social aspects. Therefore, SMEs should recognize that policy makers are devoting increasing attention to support not only SMEs' survival but also their growth and development through the provision of the right implementation instruments. SMEs' benefits are at the core of policy makers' interests because they represent the backbone of European and Italian industry and society. SMEs should turn to CCs and adopt a more holistic approach whereby the implementation of digital technologies is preceded by education and training at different organizational levels, starting with management and going on to blue-collar workers. In this regard, SMEs need to understand that CCs can be leveraged as a means for transferring innovations that have already been implemented.

As for CCs, the study has confirmed their pivotal role in supporting SMEs in the process of implementing Industry 4.0 in a more human-centered way. More specifically, the analysis revealed that, as innovation is likely to occur in more responsible ways in the near future by taking into account societal well-being and ethical factors, the CCs' relevance is likely to increase. This will only be achievable by adopting more holistic and customized solutions that include education and training as well as assistance during the entire work systems' restructuring process via design-based frameworks, which include work organization and division as well as workers' tasks. Therefore, in the near future, it is important that CCs focus even more intensely on providing integrated offerings based on long-term collaborations with client firms and on providing greater incentives for innovations that have a stronger impact on societal well-being.

Finally, regarding policy, there is a need for clearer, unified standards and codes of practices so that CCs could effectively support SMEs in implementing ethical and human-centered innovations. For instance, as SMEs' current situation is jeopardized by the threat of the digital divide, which may lead both entrepreneurs and workers to negatively perceive digital technologies, policy makers should devote increased attention in supporting SMEs through workers' upskilling and reskilling programs.

C. Limitations and future research directions

Our study entailed certain limitations, some of which offer valuable opportunities for future research. First, the study employed a qualitative methodology, which does not allow for statistical generalization. Nevertheless, this was beyond the scope of our analysis. Moreover, adopting a multiple case study enhanced external validity (see [53]). Findings from a multiple case study are usually considered more robust, as multiple cases offer varied empirical evidence and allow for comparisons, which clarify whether an emergent finding is consistently replicated across several cases.

Second, the study relied on data provided by key informants. Although we paid close attention when selecting study participants and collected and analyzed data using multiple sources (i.e., semi-structured interviews with CCs' general managers, key partners, and client firms, along with addition-al documents), we call for future research to further investigate the interactions between CCs and SMEs from a dyadic perspective. A longitudinal study would help solve this limitation and contribute to the current body of knowledge. This research direction would imply repeating the interviews over time to observe potential changes, a particularly interesting approach for future research given the imminent evolution of CCs into European Digital Innovation Hubs.

Third, we investigated six out of eight CCs ratified by Italy's Ministry of Economic Development. By the time our research began, the remaining two CCs had not been effectively structured yet; therefore, it was not possible to find the needed key informants. In this regard, future research would benefit from an extensive investigation of actors such as CCs and Digital Innovation Hubs within a broader European context.

The academic novelty of the studied phenomenon may constitute another limitation. Although the literature has suggested that external actors play a significant role in the human-centered implementation of Industry 4.0, a holistic perspective has not been established. Any studies on these topics need to be capable of coping with a low theoretical maturity. Therefore, we call for future research to further investigate human-centered Industry 4.0 to provide better empirical evidence.

APPENDIX

APPENDIX 1

INTERVIEW GUIDELINES

Interview guideline for Competence Centers

1. Could you give us some general information about your Competence Center and the type of innovation that the companies you work with implement? (ask for concrete examples)
2. What do you think are the main challenges and disadvantages that SMEs face today when implementing Industry 4.0?
3. What activities does the Competence Center implement to support companies (please provide concrete examples):
    a. in the implementation of collaborative technologies (e.g., cobots, digital twins, etc.)?
    b. in paying attention to the ergonomics of the work environment (i.e., taking into account the physical, psychological, economic, and social well-being of the workers)?
    c. in the implementation of technologies that are designed with workers' needs in mind (i.e., user-friendly technologies)?
    d. in developing training and education programs for workers?
    e. in pursuing environmental sustainability objectives for the benefit of the wider society (e.g., reducing resources waste, implementing circular economy models, etc.)?
    f. in developing ethical codes for the use of digital technologies?
4. When drafting open calls and evaluating projects, which elements do you consider the most (elements discussed above: ergonomics of the workplace, environmental sustainability, user-friendly technologies, and training programs and workers' training)? Can open calls foster a more focused development of these principles?
5. What should companies do to ensure that innovative processes include the principles of workers' self-determination, workplace ergonomics, ethics, and the like, as discussed above?
6. In the near future, what can Competence Center do to further assist companies in pursuing these goals?
7. With respect to the topics covered in the interview, would you like to add personal considerations regarding any important aspects that may have been left out?

Interview guideline for partner companies and customer companies

1. Could you give us some general information about your company (e.g., industry, turnover, employee number, etc.)?
2. In your company, which areas use Industry 4.0 (for client SMEs only)?
3. What are the main challenges related to the implementation of Industry 4.0 technologies? (Ask for firm-specific challenges when addressing customer SMEs. Ask for general challenges when addressing partners. Place more emphasis on understanding the challenges related to workers' resistance, workplace ergonomics, ethics, etc.)
4. How has the Competence Center assisted/supported the company (for key partners: How does the Competence Center assist client SMEs):
    a. in the implementation of collaborative technologies (e.g., cobots, digital twins, etc.)? (Ask for concrete examples)
    b. in paying attention to the ergonomics of the work environment (which considers workers' physical, economic, and social well-being)? (Ask for concrete examples)
    c. in the implementation of technologies that are designed with workers' needs in mind (user-friendly technologies)? (Ask for concrete examples)
    d. in developing training and education programs for workers? (Ask for concrete examples)
    e. in developing ethical codes for the use of digital technologies? (Ask for concrete examples)
    f. in pursuing environmental sustainability objectives for the benefit of the wider society (e.g., reducing resource waste, implementing circular economy models, etc.)? (Ask for concrete examples)
5. In their future evolution, what can Competence Centers do to further assist SMEs in implementing Industry 4.0 technologies?
6. With respect to the topics covered in the interview, would you like to add personal remarks on any important aspects that may have been overlooked?

APPENDIX 2
DATA COLLECTION

Case study	**Semi-structured interviews with CC's key informants**	**Semi-structured interviews with CC's partners and/or customer companies**	**Additional document data**
CC1	3 semi-structured interviews with the CC's General Manager, the CC's Node Manager, and the CC's executive researcher	1 semi-structured interview with the CC's partner company	3 open calls, 1 presentation, 80 laboratories described on the website, 36 training courses described on the website, 110 education courses described on the website, 52 webinars, 138 use cases described on the website, more than 100 blog posts
CC2	1 semi-structured interview with the CC's General Manager	-	2 open calls, 1 presentation, 47 training courses described on the website, 35 webinars, 5 case studies described on the website, 15 blog posts, 19 videos on YouTube
CC3	1 semi-structured interview with the CC's General Manager	1 semi-structured interview with the CC's customer company	2 open calls, 1 presentation, 5 training courses described on the website, 25 education courses described on the website, 36 webinars, 6 case studies described on the website, 58 blog posts, 74 videos on YouTube
CC4	1 joint interview with the CC's General Manager and Development Manager	1 semi-structured interview with the CC's partner company	5 open calls, 1 presentation, 2 laboratories described on the website, 23 projects funded described on the

			website, 77 training courses described on the website, 47 blog posts, 37 videos on YouTube
CC5	1 semi-structured interview with the CC's General Manager	1 semi-structured interview with the CC's customer company	5 open calls, 1 presentation, 1 report, 57 training courses described on the website, 39 education courses described on the website, 75 blog posts, 8 videos on YouTube
CC6	1 semi-structured interview with the CC's General Manager	1 semi-structured interview with the CC's partner company	3 open calls, 1 presentation, 8 laboratories described on the website, 37 training courses described on the website, 15 webinars, 29 blog posts, 56 videos on YouTube

APPENDIX 3
SAMPLE OF THE CODING PROCESS

First-order concepts - Open coding	**Second-order - axial coding**	**Themes**
Ethics as a topic addressed only through education Entrepreneurs' perceptions of ethics, sustainability, and workers' well-being as secondary aspects Training courses on emotive intelligence and artificial intelligence, sustainability, the circular economy, etc.	Education for sensibilization regarding social sustainability and human-centeredness	Education and training to overcome SMEs' barriers to the formation of a holistic vision of Industry 4.0
Training as anticipation Technology must meet the needs of the company, not the other way around Relevance of training for building work systems capable of integrating new technologies Courses on human-centered robotics	Training for workers' skills and competences enhancement	
Disorientation due to a lack of knowledge on and understanding of Industry 4.0 Lack of technological literacy and understanding as main barriers Fragmentation of technology suppliers Lack of technology usefulness	Education and training for overcoming entrepreneurs' negative attitudes toward Industry 4.0 technologies	
Need for workers' reassurance through education Need to create a favorable internal working environment	Workers' negative attitudes toward Industry 4.0 technologies	

REFERENCES

[1]. G. Frank et al., "Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective," Technological Forecasting and Social Change, vol. 141, pp. 341–351, 2019. https://doi.org/10.1016/j.techfore.2019.01.014

[2]. J. M. Müller, O. Buliga, and K. I. Voigt, "Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0," Technological Forecasting and Social Change, vol. 132, pp. 2–17, 2018. https://doi.org/10.1016/j.techfore.2017.12.019

[3]. D. Kiel, C. Arnold, and K. I. Voigt, "The influence of the Industrial Internet of Things on business models of established manufacturing companies – A business level perspective," Technovation, vol. 68, pp. 4–19, 2017. https://doi.org/10.1016/j.technovation.2017.09.003

[4]. M. Pinzone et al., "A framework for operative and social sustainability functionalities in Human-Centric Cyber-Physical Production Systems," Computers & Industrial Engineering, vol. 139, pp. 1-18, 2020.

https://doi.org/10.1016/j.cie.2018.03.028
[5]. Y. Liao et al., "Past, present and future of Industry 4.0—A systematic literature review and research agenda proposal," International Journal of Production Research, vol. 55, no. 12, pp. 3609–3629, 2017. https://doi.org/10.1080/00207543.2017.1308576
[6]. M. Ferreira and S. Serpa, "Society 5.0 and social development: Contributions to a discussion," Management and Organizational Studies, vol. 5, pp. 26–31, 2018. https://doi.org/10.5430/mos.v5n4p26
[7]. E. Kaasinen et al., "Empowering and engaging industrial workers with Operator 4.0 solutions," Computers & Industrial Engineering, vol. 139, pp. 1-13, 2020. https://doi.org/10.1016/j.cie.2019.01.052
[8]. A. Skarlatidou et al., "User experience of digital technologies in citizen science," Journal of Science Communication, vol. 18, no. 1, pp. 1-8, 2019. http://doi.org/10.22323/2.18010501
[9]. D. Horváth and R. Z. Szabó, "Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?" Technological Forecasting and Social Change, vol. 146, pp. 119–132, 2019. https://doi.org/10.1016/j.techfore.2019.05.021
[10]. F. Longo, A. Padovano, and S. Umbrello, "Value-oriented and ethical technology engineering in Industry 5.0: A human-centric perspective for the design of the Factory of the Future," Applied Sciences, vol. 10, no. 12, pp-1-25, 2020. https://doi.org/10.3390/app10124182
[11]. S. Nahavandi, "Industry 5.0—A human-centric solution," Sustainability, vol. 11, no. 16, pp.1-13, 2019. https://doi.org/10.3390/su11164371
[12]. J. Björkdahl, "Strategies for digitalization in manufacturing firms," California Management Review, vol. 62, no. 4, pp. 17–36, 2020. https://doi.org/10.1177/0008125620920349
[13]. K. A. Demir, G. Döven, and B. Sezen, "Industry 5.0 and human-robot co-working," Procedia Computer Science, vol. 158, pp. 688–695, 2019. https://doi.org/10.1016/j.procs.2019.09.104
[14]. A. Jerman, M. Pejić Bach, and A. Aleksić, "Transformation towards smart factory system: Examining new job profiles and competencies," Systems Research and Behavioral Science, vol. 37 no. 2, pp. 388–402, 2020. https://doi.org/10.1002/sres.2657
[15]. World Economic Forum, "The Future of Jobs Report 2018," Sept. 17, 2018. Available: https://www.weforum.org/reports/the-future-of-jobs-report-2018 (accessed March 23, 2021).
[16]. B. A. Kadir et al., "A framework for designing work systems in Industry 4.0', in Proceedings of the 22nd International Conference on Engineering Design (ICED19), pp. 5–8, 2019.
[17]. HORIZON 2020, "Secure societies – Protecting freedom and security of Europe and its citizens," the European Commission, 2019. Available: https://www.ffg.at/sites/default/files/downloads/_call/h2020-wp1820-security_en.pdf (accessed March 23, 2021)
[18]. P. O. Skobelev and S. Y. Borovik, "On the way from Industry 4.0 to Industry 5.0: From digital manufacturing to digital society," Industry 4.0, vol. 2, no. 6, pp. 307–311, 2017.
[19]. McKinsey. "Unlocking success in digital transformations." https://www.mckinsey.com/business-functions/people-and-organizational-performance/our-insights/unlocking-success-in-digital-transformations# (accessed Jan 24, 2021).
[20]. D. Witschel et al., "Riding on the wave of digitization: Insights how and under what settings dynamic capabilities facilitate digital-driven business model change," Journal of Business Economics, vol. 89, no. 8, pp. 1023–1095, 2019. https://doi.org/10.1007/s11573-019-00950-5
[21]. D. Kiel et al., "Sustainable industrial value creation: Benefits and challenges of Industry 4.0," International Journal of Innovation Management, vol 21, no. 08, pp. 1–34, 2017. https://doi.org/10.1142/9781786347602_0009
[22]. A. Moeuf et al., "The industrial management of SMEs in the era of Industry 4.0," International Journal of Production Research, vol. 56, no. 3, pp. 1118–1136, 2018. https://doi.org/10.1080/00207543.2017.1372647
[23]. M. Sosna, R. N. Trevinyo-Rodriguez, and S. R. Velamuri, "Business model innovation through trial-and-error learning: The Naturhouse case," Long Range Planning, vol. 43, pp. 383–407, 2010. https://doi.org/10.1016/j.lrp.2010.02.003
[24]. E. G. Carayannis and D. F. Campbell, "Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology," International Journal of Social Ecology and Sustainable Development (IJSESD), vol. 1, no. 1, pp. 41–69, 2010. 10.4018/jsesd.2010010105
[25]. E. G. Carayannis and D. F. Campbell, "Mode 3 and Quadruple Helix: Toward a 21st century fractal innovation ecosystem," International Journal of Technology Management, vol. 46, no. 3–4, pp. 201–234, 2009.
[26]. E. G. Carayannis et al., "The ecosystem as helix: An exploratory theory-building study of regional co-opetitive entrepreneurial ecosystems as Quadruple/Quintuple Helix Innovation Models," R&D Management, vol. 48, no. 1, pp. 148–162, 2018. https://doi.org/10.1111/radm.12300
[27]. A. Fernández-Zubieta et al., "New organizational arrangements for public-private research collaboration," Journal of The Knowledge Economy, vol. 7, no. 1, pp. 80–103, 2016. https://doi.org/10.1007/s13132-015-0292-1
[28]. E. G. Carayannis and D. F. Campbell, "Open innovation diplomacy and a 21st century fractal research, education and innovation (FREIE) ecosystem: Building on the quadruple and quintuple helix innovation concepts and the 'mode 3' knowledge production system," Journal of the Knowledge Economy, vol. 2, no. 3, pp. 327–372, 2011. https://doi.org/10.1007/s13132-011-0058-3

[29]. E. Müller and H. Hopf, "Competence center for the digital transformation in small and medium-sized enterprises," Procedia Manufacturing, vol. 11, pp. 1495–1500, 2017. https://doi.org/10.1016/j.promfg.2017.07.281
[30]. F. Longo, L. Nicoletti, and A. Padovano, "Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context," Computers & Industrial Engineering, vol. 113, pp. 144–159, 2017. https://doi.org/10.1016/j.cie.2017.09.016
[31]. P. Fantini, M. Pinzone, and M. Taisch, "Placing the operator at the centre of Industry 4.0 design: Modelling and assessing human activities within cyber-physical systems," Computers & Industrial Engineering, vol. 139, pp. 1-11, 2020. https://doi.org/10.1016/j.cie.2018.01.025
[32]. M. Breque, L. De Nul, and A. Petridis. "Industry 5.0. Towards a sustainable, human-centric and resilient European industry", 2021. https://op.europa.eu/en/publication-detail/-/publication/468a892a-5097-11eb-b59f-01aa75ed71a1/ (accessed May 12, 2021).
[33]. I. Zolotová et al.,"Smart and cognitive solutions for Operator 4.0: Laboratory H-CPPS case studies," Computers & Industrial Engineering, vol. 139, pp. 1-15, 2020. https://doi.org/10.1016/j.cie.2018.10.032
[34]. Government of Japan, "Realizing Society 5.0." Available: https://www.japan.go.jp/abenomics/_userdata/abenomics/pdf/society_5.0.pdf
[35]. K. Iwano et al., Eds. Future Services and Societal Systems in Society 5.0. Tokyo: Center for Research and Development Strategy, Japan Science and Technology Agency, 2017.
[36]. O. Onday, "Japan's society 5.0: Going beyond Industry 4.0," Business and Economics Journal, vol. 10, no. 2, pp. 1–6, 2019. https://doi.org/ 10.4172/2151-6219.1000389
[37]. P. M. Bednar and C. Welch, "Socio-technical perspectives on smart working: Creating meaningful and sustainable systems," Information Systems Frontiers, vol. 22, no. 2, pp. 281-298, 2019. https://doi.org/10.1007/s10796-019-09921-1
[38]. D. Romero, J. Stahre, M. Taisch, "The Operator 4.0: Towards socially sustainable factories of the future," Computers & Industrial Engineering, vol. 139, pp. 1-5, 2020, https://doi.org/10.1016/j.cie.2019.106128
[39]. M. Peruzzini and M. Pellicciari, "A framework to design a human-centred adaptive manufacturing system for aging workers," Advanced Engineering Informatics, vol. 33, pp. 330–349, 2017, https://doi.org/10.1016/j.aei.2017.02.003.
[40]. M. Peruzzini, F. Grandi, and M. Pellicciari, "Exploring the potential of Operator 4.0 interface and monitoring," Computers & Industrial Engineering, vol. 139, pp. 1-19, 2020, https://doi.org/10.1016/j.cie.2018.12.047.
[41]. R. Foresti, S. Rossi, M. Magnani, C. G. L. Bianco, and N. Delmonte, "Smart society and artificial intelligence: Big data scheduling and the global standard method applied to smart maintenance," Engineering, vol. 6, no. 7, pp. 835–846, 2020. https://doi.org/10.1016/j.eng.2019.11.014
[42]. D. Ivanov et al., "A dynamic model and an algorithm for short term supply chain scheduling in the smart factory industry 4.0," International Journal of Production Research, vol. 54, no. 2, pp. 386–402, 2016. https://doi.org/10.1080/00207543.2014.999958
[43]. M. Javaid et al., "Industry 5.0: Potential applications in COVID-19," Journal of Industrial Integration and Management, vol. 5, no.4, pp. 507-530, 2020. https://doi.org/10.1142/S2424862220500220
[44]. G. Ioppolo et al., "Medicine 4.0: New Technologies as Tools for a Society 5.0," Journal of Clinical Medicine, vol. 9, no. 7, pp. 1-5, 2020. https://doi.org/10.3390/jcm9072198
[45]. B. A. Kadir and O. Broberg, "Human-centered design of work systems in the transition to industry 4.0," Applied Ergonomics, vol. 92, pp. 1-14, 2021. https://doi.org/10.1016/j.apergo.2020.103334
[46]. N. Taghavi, C. Adams, and C. Berlin, "Social sustainability KPIs in operations management: A gap between the reactive and the proactive stance," in The 6th Swedish Production Symposium, pp. 1-9, 2014.
[47]. IEA, "Definition and domains of ergonomics," Açao Ergonômica, 2018. Available: https://www.iea.cc/whats/index.html (accessed Jan 20, 2021).
[48]. L. Przybilla et al., "Design thinking in digital innovation projects—Exploring the effects of intangibility," IEEE Transactions on Engineering Management, pp. 1-15, 2020. https://doi.org/10.1109/TEM.2020.3036818
[49]. M. P. Pacaux-Lemoine et al., "Designing intelligent manufacturing systems through Human-Machine Cooperation principles: A human-centered approach," Computers & Industrial Engineering, vol. 111, pp. 581–595, 2017. https://doi.org/10.1016/j.cie.2017.05.014
[50]. A. Lardo et al., "The perspective of capability providers in creating a sustainable I4.0 environment," Management Decision, vol. 58, no. 8, pp. 1759–1777, 2020. https://doi.org/10.1108/MD-09-2019-1333
[51]. H. Etzkowitz and L. Leydesdorff, "The dynamics of innovation: From National Systems and 'Mode 2' to a Triple Helix of university–industry–government relations," Research Policy, vol. 29, no. 2, pp. 109–123, 2000. https://doi.org/10.1016/S0048-7333(99)00055-4
[52]. C. Edmondson and S. E. McManus, "Methodological fit in organizational field research," Academy of Management Review, vol. 32, no. 4, pp. 1246–1264, 2007.
[53]. M. Eisenhardt and M. E. Graebner, "Theory building from cases: Opportunities and challenges," Academy of Management Journal, no. 50, vol. 1, pp. 25–32, 2007. https://doi.org/10.5465/amj.2007.24160888
[54]. R. K. Yin, Case Study Research and Applications: Design and Methods. Sage Publishing, Thousand Oaks (CA), 2014.
[55]. H. Starks and S. Brown Trinidad, "Choose your method: A comparison of phenomenology, discourse analysis, and grounded theory," Qualitative Health Research, no. 17, vol. 10, pp. 1372– 1380, 2007.

https://doi.org/10.1177/1049732307307031
[56]. M. Meyer et al., "Towards new Triple Helix organizations? A comparative study of competence centres as knowledge, consensus and innovation spaces," R&D Management, vol. 49 no. 4, pp. 555–573, 2019. https://doi.org/10.1111/radm.12342
[57]. M. Eisenhardt, "Better stories and better constructs: The case for rigor and comparative logic," Academy of Management Review, vol. 16, pp. 620–627, 1991. https://doi.org/10.5465/amr.1991.4279496
[58]. G. McCracken. The Long Interview. Sage Publishings, Newbury Park (CA), 1988.
[59]. D. A. Gioia, K. G. Corley, and A. L. Hamilton, "Seeking qualitative rigor in inductive research: Notes on the Gioia methodology," Organizational Research Methods, vol. 16, no. 1, pp. 15–31, 2013. https://doi.org/ 10.1177/1094428112452151
[60]. M. Eisenhardt, "Building theories from case study research," Academy of Management Review, vol. 14, no. 4, pp. 532–550, 1989. https://doi.org/10.5465/amr.1989.4308385
[61]. A. Strauss and J. Corbin, Basics of Qualitative Research Techniques. Thousand Oaks, CA, USA: Sage, 1998.
[62]. S. J. Taylor and R. Bogdan, Introduction to Qualitative Research Methods: The search for Meanings. Wiley-Interscience, 1984.