Organizational and managerial challenges in the path toward Industry 4.0

Lara Agostini and Roberto Filippini
Department of Management and Engineering, University of Padua, Padova, Italy

Abstract

Purpose – Currently, the expectancy that surrounds the Fourth Industrial Revolution, commonly referred to as Industry 4.0 (I4.0), is huge. In this context, the purpose of this paper is to unveil whether and how organizational and managerial practices are associated to different levels of adoption of I4.0 technologies.

Design/methodology/approach – To reach this aim, the authors carried out a survey involving Italian manufacturing firms. Then, the authors used a cluster analysis and t-test to analyze data.

Findings – Results show that two clusters of firms based on their level of adoption of I4.0 technologies (high vs low) can be identified. Then, using a t-test, the authors found statistically significant higher levels of a number of organizational and managerial practices for firms with a higher level of adoption of I4.0 technologies.

Practical implications – This paper contributes to the debate surrounding I4.0 by stressing the organizational and managerial challenges that firms willing to undertake an I4.0 transformation have to face, which goes beyond the sole application of I4.0 technologies.

Social implications – Entrepreneurs and managers need to be aware that the path toward I4.0 requires not only focusing on the application of the I4.0 technologies, but also on the development of a series of organizational and managerial practices that become key to face the fourth Industrial Revolution.

Originality/value – The authors posit here that I4.0 requires firms to bridge the capability gap, as well as overcome cultural barriers preventing entrepreneurs and managers to change their way of doing business. To this regard, this study highlights I4.0 is an all-encompassing paradigm that involves many dimensions of the firm.

Keywords New technology, Innovation, Industry 4.0

1. Introduction

The concept of Industry 4.0, identified as the fourth Industrial Revolution, was initially introduced in Germany in 2011 (e.g. Lu, 2017; Sanders et al., 2016) referring to the integration of physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries, meant to form a system in which all processes are integrated and share information in real-time frame (Hozdić, 2015). The basic principles of Industry 4.0 are therefore the connection of machines, work pieces and systems, and businesses are creating intelligent networks along the entire value chain that can control each other autonomously (Basl, 2017). This suggests that this industrial revolution is likely to affect people, companies and entire supply chains (SCs); thus, the associated level of organizational complexity is high. For this reason, manufacturing companies are looking for efficient means to accommodate the integration of I4.0 concepts into the existing setup (Sanders et al., 2017), considered that I4.0 technologies cannot be bought on the shelf, rather they require the firm to be organized to apply them properly (Porter and Heppelmann, 2015). Moreover, the way in which I4.0 technologies are integrated into existing production systems and organizational contexts is still under investigation (Tortorella and Fettermann, 2017). The literature on this topic is scant, despite it stresses that advances related to manufacturing processes ought to be accompanied by advances also at the organizational and managerial level to avoid significant but isolated gains in process efficiency and product quality (Schumacher et al., 2016). Indeed, making Industry 4.0 applications smart requires a holistic approach and sometimes a change in the business model (i.e. new value
proposition, new type of relationship with customers) (Porter and Heppelmann, 2015), which further complicates the development process (Preuveneers and Ilie-Zudor, 2017).

Within this domain, to contribute to bridge the specific gap concerning the lack of clarity on the antecedents of I4.0 implementation in manufacturing companies (Müller et al., 2018), the purpose of this paper is to examine the relationship between organizational and managerial practices and the adoption of I4.0 technologies in the Italian manufacturing industry using two methods: a cluster analysis and a regression analysis. The rationale behind the relevance of this purpose is that given the high practical and theoretical relevance of I4.0 technologies, understanding the underlying organizational and managerial dynamics of their implementation becomes necessary (Müller et al., 2018).

Therefore, this paper has a twofold relevance: from a theoretical standpoint, we propose a more encompassing approach that takes into consideration those organizational and managerial aspects that complement the adoption of digital technologies; from a practical standpoint, we suggest entrepreneurs and managers those organizational and managerial practices that may support the implementation of I4.0 technologies.

The reminder of the paper is structured as follows: in the next paragraph, we present the existing literature on the organizational and managerial practices in the context of I4.0, then we explain the methodology we used to carry out our study, followed by data analysis and results that are discussed in the final part of the paper where we also present the implications of our study.

2. Theoretical background and hypotheses

2.1 The concept of Industry 4.0

Industry 4.0 is the widely accepted term used to refer to the Fourth Industrial Revolution, despite a shared definition does not exist yet. Due to a proliferation of studies in recent years, not only by academics but to a larger extent by consultants, a number of other words are used as synonyms, as a cyber-physical system (CPS), smart factory/manufacturing and Internet of Things (Liao et al., 2017), with a bit of confusion among them. To clarify things, we can start by defining CPS as transformative technologies for managing interconnected systems between its physical assets and computational capabilities (Lee et al., 2015). The integration of CPS with innovative production, logistics and services practices would lead to an I4.0 factory (Lee et al., 2015). Indeed, I4.0 is often identified with a number of technologies involving all these aspects, as Internet of Things, Big Data and analytics, cybersecurity, which belong to the CPS domain, to which other production technologies are added, as advanced manufacturing systems, additive manufacturing, 3D printing (e.g. Tortorella and Fettermann, 2017; Rußmann et al., 2015; Deloitte, 2015). In line with that, in 2016, the Italian Ministry of Economic Development[1] has delimited the scope of Industry 4.0 to nine technologies (i.e. Industrial Internet of Things, cloud computing, cybersecurity, Big Data and analytics, simulation, horizontal and vertical integration, added manufacturing, advanced manufacturing solutions, augmented reality) and designed a national plan for Industry 4.0 to support firms in exploiting the potential of the opportunities the fourth Industrial Revolution offer.

In the last years, different reports have been published that describe the different maturity levels of firms with regard to Industry 4.0 and posit the organizational and managerial features that companies registering a higher maturity level of Industry 4.0 are likely to have (e.g. Kane et al., 2017; Perego et al., 2017). Despite these reports argue there are some patterns in the adoption of I4.0 technologies, and stress the significance of organizational and managerial issues to support such implementation, they do not prove it empirically. Therefore, this paper aims to bridge this first gap in the literature by exploring whether different groups of firms can be identified based on their level of adoption of I4.0 technologies and whether they are also characterized by different organizational and managerial practices.
2.2 Organizational and managerial issues in the I4.0 context

As anticipated, the literature focusing on the organizational and managerial facets of I4.0 is still scant, which is due to the relative newness of the topic of I4.0, as well as to the absence of a reference model for what concerns the organizational and managerial context supporting firms in the path toward I4.0.

With the aim of contributing to bridge this gap, the purpose of this paper is to analyze the I4.0 behavior of manufacturing firms, classifying them according to their level of implementation of I4.0 technologies, and unveiling whether organizational and managerial practices may affect these implementation levels.

To reach this purpose, first, we reviewed the academic and practitioner literature within the domain of I4.0, with a particular attention on those articles focusing on the organizational and managerial practices.

According to the view that I4.0 is likely to affect people, production processes and entire SCs (Hofmann and Rüsch, 2017), extant literature address organizational and managerial practices at three levels: the human resource (HR) level, the firm level and the SC level. The extant literature discusses these different organizational and managerial practices in the domain of I4.0, but without testing empirically the association with the implementation of I4.0 technologies and without taking such an overarching approach, which is the aim of this study.

2.2.1 Organizing for I4.0 – HR. At an HR level, Industry 4.0 propagates the idea of workers that increasingly will focus on creative, innovative and communicative activities (Erol, Jäger, Hold, Ott and Sihn, 2016). Indeed, all the challenges that I4.0 poses require continuous innovation and learning, which is dependent on people capabilities (Shamim et al., 2016). Therefore, the role of employees during industrial revolutions is very important (Sirotek and Firlus, 2016) and Industry 4.0 requires a labor force with high skill levels (Balasingham, 2016). This includes developing and establishing training and workshops for the employees, with the focus on new core tasks such as how to manage and control digitized systems. Therefore, training and continue professional development of employees are of major importance to succeed in early stages of the transition toward digitalization (Kagermann et al., 2013).

Beyond skills, individuals are embedded in a social context, which requires the ability to communicate, cooperate and to establish social connections and structures with other individuals and groups. The full digital integration and automation of whole manufacturing processes in the vertical and horizontal dimensions imply that workers will be responsible for a broader process scope and will need the ability to understand relations between processes, the information flows and to cooperate ad hoc in finding appropriate solutions for particular problems (Erol, Jäger, Hold, Ott and Sihn, 2016).

The possibility for employees to benefit from more responsibility and personal development thanks to the implementation of Industry 4.0 needs to be stimulated by managers (Kagermann et al., 2013). Managers must be able to build or act as mediators that enable social processes and decision processes (Erol, Jäger, Hold, Ott and Sihn, 2016; Adolph et al., 2014). Therefore, with managers’ support to employees, which reduces distance between the workers and the managers of the plant through the reduction of hierarchical levels, higher autonomy of teams and workers, a wider distribution of decision authority can facilitate organizational learning and innovations by increasing employee participation (Bartezzaghi et al., 2017; Shamim et al., 2016; Schuh et al., 2014).

2.2.2 Organizing for I4.0 – firm processes. Overall, the literature (e.g. Tamás and Illés, 2016) stresses that process improvement becomes necessary in the context of Industry 4.0. In this domain, the literature has dedicated some attention to lean production (LP). Von Haartman et al. (2016), based on a survey in manufacturing companies from developed
countries, indicate that LP maybe a prerequisite for digital technologies used in production. Overall, Kolberg et al. (2017) affirm that LP can be considered as a complement to the technological point of view emphasized in I4.0. LP and I4.0 share common features, as decentralized and simple structures over large and complex systems (Zuehlke, 2010) to make an example, thus suggesting a possible interrelation between the two phenomena. Furthermore, such a changing environment requires that companies must be able to quickly adapt their production methods, being capable of continuously improving their production processes and also of developing them further (Cachay and Abele, 2012). However, contradictory evidences found in the literature (e.g. Erol, Jäger, Hold, Ott and Sihn, 2016; Sanders et al., 2016; Schumacher et al., 2016) indicate that the comprehension of such association still needs to be deepened and better explored (Tortorella and Fettermann, 2017; Sanders et al., 2016).

Considered that the digital infrastructure and its connectivity with the internet is one of the core values under Industry 4.0 (Davies, 2015), the existing capabilities of manufacturing firms related to the ICT infrastructure plays a key role within the process of digitalization (Balasingham, 2016; Stock and Seliger, 2016). Actually, the existence of a modern ICT infrastructure seems to be an essential prerequisite to the activities at the core of I4.0, as data transmission or system integration (Erol, Schumacher and Sihn, 2016; Schumacher et al., 2016).

2.2.3 Organizing for I4.0 – SC. At an SC level, integration and collaboration seem to be key in the implementation of I4.0. Indeed, I4.0 has both vertical and horizontal integration at its core: integration of the various IT systems used in the different stages of the manufacturing and business planning processes within a company and between several different companies, integration of the various IT systems at the different hierarchical levels, and integration throughout the engineering process so that the digital and real worlds are integrated across a product’s entire value chain and across different companies (Liao et al., 2017). Consequently, the flow of materials, information and knowledge across the whole SC is likely to be a significant driver toward I4.0 that calls for increasing openness and adaptability (Wang et al., 2015). Regarding the flow of material across companies, just-in-time (JIT) primarily focuses on the supplier-buyer relationship and it seeks for a demand-tailored realization of goods exchange processes aiming to increase overall SC flexibility and agility (Wang et al., 2015). Therefore, JIT may enable actors to exchange and act upon real-time information in a coordinated end-to-end fashion (Hofmann and Rüsch, 2017). Regarding information and knowledge flows, Schuh et al. (2014) assert that the availability of information along the value chain, as well as the soft component of cooperation across all borders, technologies and activities facilitate the path toward I4.0. Wang et al. (2015) confirm that the increasing connectivity and capabilities of computational systems drive the creation of entirely new systems characterized by, among others, a new cross-domain collaboration. Indeed, open innovation (OI) is commonly included in maturity models to assess a firm readiness to Industry 4.0, and it is considered an important element demonstrating a firm network orientation that I4.0 requires (e.g. Schumacher et al., 2016; Prause, 2015).

Based on these evidences from the literature, we formulated two sets of hypotheses: the first one aims to verify the existence of different profiles of firms based on the adoption of I4.0 technologies and organizational and managerial practices, whereas the second one intends to test the relationship between the implementation of I4.0 technologies and organizational and managerial:

$H1$. Manufacturing firms can be grouped based on their level of implementation of I4.0 technologies, where firms within each group will share similar characteristics as far as the organizational and managerial practices are concerned.
H2. Higher levels of organizational and managerial practices positively impact the implementation of I4.0 technologies in manufacturing firms.

H2a. Higher levels of organizational and managerial practices at the HR level positively impact the implementation of I4.0 technologies in manufacturing firms.

H2b. Higher levels of organizational and managerial practices at the firm process level positively impact the implementation of I4.0 technologies in manufacturing firms.

H2c. Higher levels of organizational and managerial practices at the SC level positively impact the implementation of I4.0 technologies in manufacturing firms.

Figure 1 depicts the framework that provides theoretical support to this research.

3. Methodology

Based on the purpose of our study, we decided to rely on primary data that are then analyzed by means of statistical quantitative techniques, namely, a cluster analysis, complemented by a t-test, and a regression analysis. Details of this procedure are explained in the following subsections.

3.1 Sample

Considered that the study is supposed to provide a general overview on the level of implementation of I4.0 technologies in Italian manufacturing firms and the associated managerial and organizational challenges, 1,000 Italian manufacturing firms were randomly selected, independently of their size. We used the AIDA database that contains economic financial data of Italian firms. Then, we sent an e-mail to the owner or the managing director of all the identified firms inviting them to participate to an on-line survey on the theme of I4.0. After two recalls, 257 useful questionnaires were received, corresponding to a response rate of 25.7 percent. As far as firm size is concerned, 32.1 percent are small, 33 percent are medium and 34.9 percent are large firms.
3.2 Measures

In this study, to measure the adoption level of I4.0 technologies, we identified nine inter-related Industry 4.0 technologies, as suggested by the Italian Ministry of Economic Development in 2016. This approach follows the recent article by Tortorella and Fettermann (2017), who build on the assumption that Industry 4.0 is based on enabling technologies. We asked whether firms are adopting now or are formally planning to adopt in the near future each one of these technologies at a process/SC and product level (binary variable assuming values 0 or 1). Then, we summed the technologies that were already adopted at a process/SC and product level, thus obtaining the I4.0 TECH_PROC and I4.0 TECH_PROD variables. The maximum value that I4.0 TECH_PROC may assume is 18 (adoption of the nine technology at the process and SC level) and I4.0 TECH_PROD 9.

Instead, the following constructs and associated items were assessed on a Likert scale ranging from 1 (completely disagree) to 5 (completely agree).

Regarding LP, scientific journals have published a number of articles that focus on describing and characterizing the content of LP; yet, there is not a precise and agreed upon way of defining or measuring LP (Tortorella and Fettermann, 2017). Therefore, we asked the intensity of application of a series of lean methods taken from the literature, and the factor analysis divided them into two different factors, as Table II shows. The former includes 5S, written work procedures and the creation of standards and regular control of standard respect, which refers to organizational methods (LEAN_ORG), whereas the latter comprises set-up time reduction in production, kanban and pull systems in production, balancing production processes and waste reduction, which refers to methods applied in production (LEAN_PROD). This is in line with the tendency toward creating groups of LP methods (e.g. Matt and Rauch, 2013).

The three-item scale to measure continuous improvement and learning (CONT_IMPR) is taken from Liu et al. (2006), and it focuses on the extent to which organization members value and engage in activities that facilitate continuous product and process improvement and learning.

Just-in-time delivery by suppliers (JIT_SUPP) measures whether vendors have been integrated into production in terms of making frequent or JIT delivery and is taken from Matsui (2007). Along the same line, just-in-time link with clients (JIT_CL) assesses whether the plant has applied the JIT delivery concept and the pull system concept in the operational link with clients. Both are measured using a three-item scale.

The four-item scale for information flow integration (SC_INT) is defined as the degree to which a focal firm uses global optimization with its SC partners to manage the extent of operational, tactical and strategic information sharing that occurs between a focal firm and its SC partners (Rai et al., 2006).

Employees’ skills for innovation (SKILLS) is composed of three items indicating the overall skill, expertise and knowledge levels of an organization employees. Internal social capital is measured through a three-item scale that reflects the value embedded in the interactions among employees and concerns the quality of such relationships in terms of employees’ knowledge exchange habits, propensity to collaborate and work in groups. Both these scales are taken from Subramaniam and Youndt (2005).

The three-item scale for task-related training for employees (TRAIN) factor is reflected by a firm’s effort to upgrade employee skills through continual and regular training activities.

The measurement scale used to measure the organizational support context (ORG_CNTX) has a theoretical foundation in Gibson and Birkinshaw’s (2004) work and captures the extent to which management systems in organizations encourage people to challenge outmoded practices and devote considerable effort to developing subordinates, while pushing decisions down to the lowest appropriate level.
Then, we examined also firms’ inclination toward OI and the ICT level (ICT). As far as OI is concerned, we asked firms whether they have regular collaborations for innovation with universities/research centers, suppliers, clients, other innovative firms and consultants (Landry et al., 2002), thus obtaining a firm OI breadth by summing the number of diverse actors a firm has a collaboration with, which ranges from 1 to 5.

As for ICT, we asked whether firms have an ERP and, if so, for which functions, as well as whether they have implemented data exchange with suppliers and clients, and collection and analysis of machine data. On such basis, we built an ICT index ranging from 1 (no ERP or ERP only for a few functions) to 5 (ERP for all functions, data exchange and collection and analysis of machine data).

To carry out the regression analyses, we aggregated these constructs into the macro-variables HR, firm process (FIRM) and SC by calculating the mean value, in line with the approach used by previous studies (e.g. Agostini and Nosella, 2017; Furlan and Vinelli, 2018).

3.3 Statistical procedure

Our methodology consists of a confirmatory factor analysis, a cluster analysis, complemented by a t-test, and a regression analysis to assess the relationship between organizational and managerial practices and the level of adoption of I4.0 technologies. Principal component analysis with promax was conducted to identify and confirm the different factors under each construct in our conceptual model using the software SPSS. Almost all items were significantly related to their underlying constructs, providing support for convergent validity and factor loadings ranged from 0.65 to more than 0.9, with most of the items greater that 0.7 (see Table I). To ensure convergent validity, we eliminated items that load greater than 0.45 in more than one factor. We further assessed discriminant validity by examining Cronbach’s $\alpha$, which showed $\alpha$s definitely higher than the acceptable threshold of 0.60 (Nunally, 1978).

After carrying out the confirmatory factor analysis, the cluster analysis was run with SPSS. The technique of cluster analysis is useful to summarize the data and, in an explorative way, to group the different categories of firms into “clusters” according to their similarities or dissimilarities in terms of certain characteristics (Cantwell and Janne, 1999), here the adoption of I4.0 technologies. In this specific case, the method applied to form the clusters is the K-means. According to the aim of this paper, the variables employed in the cluster analysis to define groups referred to the adoption of I4.0 technologies (I4.0 TECH_PROC, I4.0 TECH_PROD), computing the average of the items score of each construct. After conducting the cluster analysis, a t-test was carried out to verify if the identified clusters of firms showed significant difference in terms of organizational and managerial practices using the software Stata.

Lastly, to corroborate these results, a negative binomial regression analysis, appropriate for non-negative integer count dependent variables (Hausman and Griliches, 1984), was performed to test the impact of organizational and managerial practices at the HR, firm process and SC level on the level of implementation of I4.0 technologies both at the product and process level. Additionally, firm size, measured by means of dummy variables for small, medium and large firms, was introduced as a control variable.

4. Results

4.1 Results of the cluster analysis

Regarding H1, the results of the cluster analysis show that three groups of firms can be identified based on their level of adoption of I4.0 technologies: 12.4 percent of firms belong to Cluster 1 (the “high” group, called Adopters), 38.2 percent to Cluster 2 (the “medium” group, called Beginners) and 49.4 percent to Cluster 3 (the “low” group, called non-adopters), presenting a decreasing level of adoption of I4.0 technologies both at a process/SC and product level.
## Table I.

Results of the factor analysis

<table>
<thead>
<tr>
<th>Construct</th>
<th>Id</th>
<th>Items</th>
<th>Factor loading</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skills for innovation</strong> (Subramaniam and Youndt, 2005)</td>
<td></td>
<td>Indicate your level of agreement (1 = strongly disagree; 5 = strongly agree) with the following sentences regarding your employees in your company in the last years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SKILLS_1</td>
<td>Our employees are highly skilled to develop innovations</td>
<td>0.840</td>
<td>0.749</td>
</tr>
<tr>
<td></td>
<td>SKILLS_2</td>
<td>Our employees are highly skilled related to digital technologies</td>
<td>0.836</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SKILLS_3</td>
<td>Our employees are widely considered the best in our industry</td>
<td>0.744</td>
<td></td>
</tr>
<tr>
<td><strong>Training for employees</strong></td>
<td></td>
<td>Indicate your level of agreement (1 = strongly disagree; 5 = strongly agree) with the following sentences regarding training for employees in your company in the last years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TRAIN_1</td>
<td>Our plant employees receive training and development in workplace skills, on a regular basis</td>
<td>0.915</td>
<td>0.872</td>
</tr>
<tr>
<td></td>
<td>TRAIN_2</td>
<td>Management at this plant believes that continual training and upgrading of employee skills is important</td>
<td>0.846</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TRAIN_3</td>
<td>Our employees regularly receive training to improve their skills</td>
<td>0.859</td>
<td></td>
</tr>
<tr>
<td><strong>Internal social capital</strong> (Subramaniam and Youndt, 2005)</td>
<td></td>
<td>Indicate your level of agreement (1 = strongly disagree; 5 = strongly agree) with the following sentences regarding collaboration among employees in your company in the last years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ISC_1</td>
<td>Our employees are skilled at collaborating with each other to diagnose and solve problems</td>
<td>0.822</td>
<td>0.885</td>
</tr>
<tr>
<td></td>
<td>ISC_2</td>
<td>Our employees share information and learn from one another</td>
<td>0.865</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ISC_3</td>
<td>Our employees interact and exchange ideas with people from different areas of the company</td>
<td>0.892</td>
<td></td>
</tr>
<tr>
<td><strong>Organizational support context</strong> (Birkinshaw and Gibson, 2004)</td>
<td></td>
<td>Indicate your level of agreement (1 = strongly disagree; 5 = strongly agree) with the following sentences regarding managers in your company in the last years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ORG_CNTX_1</td>
<td>Managers in my organization devote considerable effort to developing subordinates</td>
<td>0.839</td>
<td>0.862</td>
</tr>
<tr>
<td></td>
<td>ORG_CNTX_2</td>
<td>Managers in my organization push decisions down to the lowest appropriate level</td>
<td>0.904</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ORG_CNTX_3</td>
<td>Managers in my organization issue creative challenges to their people instead of narrowly defining tasks</td>
<td>0.891</td>
<td></td>
</tr>
<tr>
<td><strong>Continuous improvement</strong> (Flynn et al., 1999)</td>
<td></td>
<td>Indicate your level of agreement (1 = strongly disagree; 5 = strongly agree) with the following sentences regarding continuous improvement in your company in the last years</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CONT_IMPR_1</td>
<td>If we are not constantly improving and learning, our performance will suffer in the long term</td>
<td>0.742</td>
<td>0.607</td>
</tr>
<tr>
<td></td>
<td>CONT_IMPR_2</td>
<td>We believe that improvement of a process is never complete; there is always room for more incremental improvement</td>
<td>0.770</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CONT_IMPR_3</td>
<td>We strive to continually improve all aspects of products and processes, rather than taking a static approach</td>
<td>0.670</td>
<td></td>
</tr>
</tbody>
</table>

(continued)
Table II summarizes the mean value and standard deviation of the adoption of I4.0 technologies at a process/SC and product level used as clustering variables. Of course, the ANOVA confirms level of adoption of I4.0 technologies both at the process/SC and product level is significantly different between the three clusters. Moreover, we can notice that the adoption of I4.0 technologies is higher at the process than at the product level.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Id</th>
<th>Items</th>
<th>Factor loading</th>
<th>Cronbach's α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean methods (Matt and Rauch, 2013)</td>
<td>LEAN_1</td>
<td>5S</td>
<td>0.713</td>
<td>0.736</td>
</tr>
<tr>
<td></td>
<td>LEAN_2</td>
<td>Written work procedures</td>
<td>0.811</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LEAN_3</td>
<td>Creation of standards and regular control of standard respect</td>
<td>0.850</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LEAN_4</td>
<td>Set-up time reduction in production</td>
<td>0.786</td>
<td>0.830</td>
</tr>
<tr>
<td></td>
<td>LEAN_5</td>
<td>Kanban and pull systems in production</td>
<td>0.806</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LEAN_6</td>
<td>Balancing production processes</td>
<td>0.872</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LEAN_7</td>
<td>Waste reduction</td>
<td>0.831</td>
<td></td>
</tr>
<tr>
<td>JIT with suppliers (Matsui, 2007)</td>
<td>JIT_SUPP_1</td>
<td>Our suppliers deliver to us on a just-in-time basis</td>
<td>0.781</td>
<td>0.722</td>
</tr>
<tr>
<td></td>
<td>JIT_SUPP_2</td>
<td>We receive daily shipments from most suppliers</td>
<td>0.650</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JIT_SUPP_3</td>
<td>Our suppliers are linked with us by a pull system</td>
<td>0.849</td>
<td></td>
</tr>
<tr>
<td>JIT with clients (Matsui, 2007)</td>
<td>JIT_CL_1</td>
<td>Our clients receive just-in-time deliveries from us</td>
<td>0.785</td>
<td>0.701</td>
</tr>
<tr>
<td></td>
<td>JIT_CL_2</td>
<td>We always deliver on time to our clients</td>
<td>0.825</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JIT_CL_3</td>
<td>We can adapt our production schedule to sudden production stoppages by our clients</td>
<td>0.756</td>
<td></td>
</tr>
<tr>
<td>Information flow integration</td>
<td>SC_INT_2</td>
<td>Production and delivery schedules are shared across the supply chain</td>
<td>0.897</td>
<td>0.879</td>
</tr>
<tr>
<td></td>
<td>SC_INT_3</td>
<td>Supply chain members collaborate in arriving at demand forecasts</td>
<td>0.844</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SC_INT_4</td>
<td>Our downstream partners (e.g. distributors, wholesalers, retailers) share their actual sales data with us</td>
<td>0.759</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SC_INT_5</td>
<td>Inventory data are visible at all steps across the supply chain</td>
<td>0.901</td>
<td></td>
</tr>
</tbody>
</table>

Table I.
The subsequent step, i.e. analysis of difference between groups in terms of organizational and managerial practices, reveals interesting insights. Results highlight that the Adopters, characterized by higher levels of adoption of I4.0 technologies, registers also significantly higher levels of organizational practices than Beginners and non-adopters at all levels, as Table III exhibits. It is interesting to notice that differences in terms of organizational and managerial practices between beginners and non-adopters are not all statistically significant. More specifically, the two clusters differ in terms of skills for innovation, use of lean methods, use of ICT and collaboration with external entities.

4.2 Results of the regression analysis
As far as $H2$ is concerned, we used a linear regression model to test the relationship between the organizational and managerial practices at the HR, firm process and SC level and the level of implementation of I4.0 technologies.

As Table IV shows, organizational and managerial practices at the firm process and SC level seem to have a positive impact on the level of implementation of I4.0 technologies at the product and process level, thus supporting $H2b$ and $H2c$. Contrarily, organizational and managerial practices at the HR level seem not to affect the implementation of I4.0 technologies at the product or process level, which does not provide support for $H2a$.

Taking the evidences emerging from the cluster analysis into consideration, this result was surprising and suggested us that maybe organizational and managerial practices at the HR level could play a different role in the dynamics leading to the implementation of I4.0 technologies.
of I4.0 technologies. On such grounds, we checked whether they could act as moderators, i.e. if they strengthen the relationship between organizational and managerial practices at the firm process and SC level and the level of implementation of I4.0 technologies. To this purpose, we conducted a two-group analysis distinguishing the group of firms that register levels of organizational and managerial practices higher than the mean of the sample (i.e. the HIGH group) from the group of firms that have values of the moderating variable lower than the mean of the sample (i.e. the LOW group).

Table V shows that the impact of organizational and managerial practices at the firm process and SC levels are significant (vs not significant) or higher (vs lower) in the HIGH group with respect to the LOW group; therefore, organizational and managerial practices at the HR level act as a moderator. Moreover, the Chow tests, assessing statistical difference between the regression coefficients of the HIGH and LOW groups, result significant, which provides further support to these results. Figure 2 depicts the final model.

5. Discussion and conclusions
The aim of this paper was to analyze the I4.0 behavior of manufacturing SMEs, classifying them according to their level of implementation of I4.0 technologies, and unveiling whether organizational and managerial practices may affect these implementation levels.

Data analyses, based on a survey involving Italian manufacturing firms, show the emergence of three clusters with respect to the implementation of I4.0 technologies, the adopters, the beginners and the non-adopters, that present also significantly different levels of organizational and managerial practices. Moreover, the regression shows that organizational and managerial practices at the firm process and SC level have a direct

| Table V. Results of the regression analysis – moderation of organizational and managerial practices at the human resource level |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|                                    | Dep. Var.: I4.0 TECH_PROD       |                                    | Dep. Var.: I4.0 TECH_PROC       |                                    |                                    |
|                                    | Coefficient (p-value)           | Coefficient (p-value)             | Coefficient (p-value)           | Coefficient (p-value)             | Coefficient (p-value)            |
| Firm                               | HIGH group                      | LOW group                        | Chow test                       | HIGH group                      | LOW group                        | Chow test                       |
| FIRM                               | 0.982* (0.060)                  | 0.480 (0.250)                    | \( p = 0.032^{**} \)            | 2.245*** (0.001)                | 1.224* (0.059)                   | \( p = 0.035^{**} \)            |
| SC                                 | 0.943*** (0.017)                | 0.398 (0.291)                    | \( p = 0.017^{**} \)            | 0.952*** (0.045)                | 0.851 (0.145)                    | \( p = 0.023^{**} \)            |
| Size_small                         | 0.622 (0.360)                   | -0.726 (0.271)                   | \( p = 0.145 \)                 | -1.833*** (0.043)               | -0.335 (0.740)                   | \( p = 0.056^{*} \)             |
| Size_medium                        | -0.052 (0.938)                  | 0.255 (0.592)                    | \( p = 0.234 \)                 | 1.372 (0.127)                   | 0.638 (0.384)                    | \( p = 0.396 \)                 |
| Pseudo \( R^2 \)                   | 0.12                            | 0.06                            |                                  | 0.13                            | 0.07                            |

Notes: **,***,**Significant at \( p < 10; p < 5; p < 1 \) percent levels, respectively.

![Figure 2](The_final_model)
impact on the implementation of I4.0 technologies, whereas organizational and managerial practices at the HR level seem to act as a moderator.

As far as the first evidence is concerned, we can notice there is a small group of firms that are implementing I4.0 technologies more intensely and these firms are those that register also significantly higher levels of all investigated organizational and managerial practices with respect to all other sampled firms. Considered the time lag between organizational and managerial practices and the implementation of I4.0 technologies, these results seem to point to the fact that firms need to be shaped at all levels to reach high levels of implementation of I4.0 technologies. Instead, there seem to be some organizational and managerial factors that pave the way to the introduction of new I4.0 technologies, namely, highly skilled employees regarding innovation and digital technologies, the adoption of lean methods, the use of ICT tools and the ability to collaborate with external entities for innovation.

To further corroborate our results, we carried out 15 in-depth interviews with managers of sampled firms who explained they were not surprised. Indeed, they agreed upon the fact that workers are the crucial link because the technology is not intelligent per se, rather it needs to be set and implemented properly to work well. Therefore, expertise of workers, overall at lower levels, is crucial at an initial stage. Moreover, they recognize that I4.0 technologies require a deep knowledge of processes and lean philosophy soundly helps in achieving such knowledge and allows not digitalizing waste. They also added that the presence of ERP for all functions and systems to exchange data with suppliers and clients are required to install, for example manufacturing execution sytems that are able to generate useful information from data collected through intelligent sensors positioned in the production lines. This belongs to the internet of things domain and it represents where many firms frequently start from. Finally, yet importantly, the higher inclination toward OI highlight a higher propensity toward slackening the boundaries of the firm, thus being ready to act as part of a network instead of a stand-alone entity, which is at the basis of the I4.0 approach.

The second evidence provides further confirmation to the results of the exploratory factor analysis, as well as to the theoretical idea prompted by Schumacher et al. (2016) that advances at the organizational and managerial level are needed to get advances related to manufacturing processes but avoiding significant but isolated gains at the production level. Managers we discussed these results with also confirmed the I4.0 transformation needs to be prepared at the organizational and managerial level before dealing with the technology. Indeed, I4.0 technologies do not stand for I4.0 factory that is likely to require an overarching approach embracing different perspectives and different practices within and outside firms. However, further research is required to shed more light on these issues.

Therefore, this study opens the way to research on organizational and managerial practices as antecedents of I4.0 and on the hierarchy among antecedents. On such basis, this paper contributes to the debate surrounding I4.0 by stressing the organizational and managerial challenges that firms willing to undertake an I4.0 transformation have to face, which goes beyond the sole application of I4.0 technologies. Moreover, the fact that three different clusters emerge based on the level of implementation of I40 technologies and they are characterized by different levels of organizational and managerial practices also suggests that I4.0 implementation is not an on-off issue, but rather a pathway that could benefit from a longitudinal approach. Indeed, the issue of time is not considered here, but it could reveal more precise insights regarding which organizational and managerial practices are more effective at the different stages of the path toward I4.0.

From a more practical standpoint, being I4.0 an all-encompassing paradigm that involves many dimensions of the firm, i.e. technological, managerial, organizational and
financial, entrepreneurs and managers require an overarching perspective on the transformation their firms need to undergo. Indeed, I4.0 requires not only focusing on the application of the I4.0 technologies, but also on the development of a series of organizational and managerial practices that become a key to face the fourth Industrial Revolution. More specifically, managers should employ and take advantage of employees who are skilled in innovation and digital technologies, adopt a lean philosophy, upgrade their ICT tools with particular reference to internal and external integration and open their firm boundaries to lay the basis for an I4.0 factory. Then other organizational and managerial practices at the HR, firm and SC level come into play to boost the implementation of I4.0 technologies. Therefore, I4.0 is a challenge to be dealt with in the long run because it needs a gradual and structured process based on a fertile ground at the organizational and managerial level, which is likely to require further investigation.

We recognize this is a preliminary study and other variables may be taken into examination as antecedents to the implementation of I4.0 technologies, as well as other countries and other contexts. We are also aware that the implementation of I4.0 technologies could, in turn, generate some changes at the organizational and managerial level, thus investigating the way around could reveal useful insights.

Note

References


**Further reading**


**Corresponding author**
Roberto Filippini can be contacted at: roberto.filippini@unipd.it