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The drivers of the digital transformation in the healthcare industry: An empirical analysis in Italian hospitals

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ABSTRACT

In recent years, driven by the spread of the COVID-19 pandemic, digital transformation in the healthcare sector is becoming increasingly important. Digital healthcare technologies, if adopted in a targeted manner and implemented in a cost-effective way, make it possible to reduce healthcare inequalities, improve the quality of healthcare provided and increase the well-being of citizens. The importance of digital transformation in healthcare is also attracting interest from academics. However, at present, there are few studies aimed at examining the degree of digital transformation in healthcare and the drivers of the adoption and implementation of digital solutions by healthcare facilities. This study aims to fill this gap by analysing the level of digital transformation of Italian hospitals and the factors that can affect this level of digital transformation. The analysis, conducted on a sample of 103 hospitals, shows a positive and significant impact of the hospital size, hospital age and hospital teaching status on the level of digital transformation. Furthermore, in relation to hospital complexity, it shows a positive effect of the presence of the emergency room and a non-significant influence of the number of hospital departments on the level of digital transformation.

1. Introduction

In recent years, digital transformation has been evolving the business models of companies operating in all sectors globally. It represents "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" (Vial, 2019, p. 118). The pervasive characteristics of digital technologies are changing the way businesses and organizations of all sizes are produced, traded and communicated (Rippa and Secundo, 2019; Elia et al., 2020; Raimo et al., 2021; Verhoef et al., 2021). In this regard, the changes brought about by digital transformation represent important and powerful driving forces of the current economic system (Cohen et al., 2017; Nambisan, 2017; Vitolla et al., 2020; Salvi et al., 2021).

Within the various sectors, digital transformation has taken on a particularly important role in healthcare and, more specifically, in hospitals (Agarwal et al., 2010; Sousa et al., 2019; Marques and Ferreira, 2020; Kraus et al., 2021; Massaro, 2021). An important push towards the digital transformation of hospitals was represented by the spread of the COVID-19 pandemic (Cobianchi et al., 2020a, 2020b; Drago et al., 2021; Madhavan et al., 2021; Tortorella et al., 2021). In this regard, according to a report drawn up by Deloitte (2020), about 65% of healthcare organizations have increased the adoption of digital technologies following the spread of this pandemic in order to support working methods and provide assistance to patients. Digital transformation is considered one of the most effective responses to face the pressures of stakeholders, improve the quality of health services and reduce costs (Locatelli et al., 2010, 2012; Secundo et al., 2018; Saifudin et al., 2021). Furthermore, digital health solutions such as electronic health records, monitoring equipment, tele-health, electronic communications, data analysis, and web and cloud-based tools, if implemented in a targeted manner, have the potential to reduce health inequalities and increase well-being of users through a substantial change in the way in which care and health services are provided to patients (Or et al., 2014; Mihailescu and Mihailescu, 2018; Spanò et al., 2021; Cerchione et al., 2022). In this regard, for example, the digitalisation of health records, understood as the conversion from paper format into computerized form, has consequently improved the overall quality of health care provided, also leading to an increase in the provision of care and patient safety (Car et al., 2008).

The importance of digital transformation in the healthcare sector has led to the emergence of numerous policies, programs, regulations and

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directives aimed at supporting the digitalisation of healthcare systems. These interventions mainly concerned the European context. In particular, in 2018, the European Commission published a final communication that detailed the previous actions taken to promote the digitalisation of health and a series of further commitments to further promote digital transformation (Deloitte, 2020).

However, despite the political interventions, the path towards the digital transformation of hospitals still presents some problems. First, most digitalisation projects have not lived up to expectations (Preko and Boateng, 2020). In this regard, Agarwal et al. (2010) found that health care improvements related to digital transformation often fail to materialize. Other authors have instead highlighted problems in the use of electronic health records (Lorenzi et al., 2008; Preko and Boateng, 2020) related to delays, safety and costs (Avison and Young, 2007; Mihailescu and Mihailescu, 2018). A second problem is instead connected to the different levels of digital maturity of health facilities not only between different European countries but also within individual countries (Deloitte, 2020). The contradictory results in relation to the digital transformation of healthcare and the different levels of digital maturity of healthcare facilities have attracted the attention of academics (Reis et al., 2018; Kraus et al., 2021). In this regard, a recent systematic literature review conducted by Marques and Ferreira (2020) highlighted a sharp increase in the last twenty years of studies on the topic of digital transformation in healthcare. However, the authors highlighted that these studies focused mainly on specific issues such as integrated management, medical images, electronic medical records and virtual services. The contributions that dealt with the digital transformation of healthcare organizations from a broader perspective focused mainly on the identification of the different digital technologies implemented, on the advantages and benefits deriving from the implementation of digital technologies and on the barriers and challenges associated with the implementation of these technologies (Tortorella et al., 2020a). However, there is an important gap in the academic literature since only a limited number of studies have examined the factors capable of influencing the level of digital transformation of healthcare organizations. Furthermore, these studies focused only on emerging economies (Tortorella et al., 2020a) and on African countries (Preko and Boateng, 2020).

This study aims to fill this important gap in the literature by analyzing the level of digital transformation of the healthcare organizations and the factors that can affect this level of digital transformation. In particular, this study aims to answer the following research question:

RQ: What are the factors that influence the level of digital transformation of hospitals?

To answer the research question, this study adopts a contingency theory perspective, focusing attention on the impact of the internal factors represented by the hospitals' characteristics. More specifically, this study examines the impact of hospital size, hospital complexity, hospital age and hospital teaching status on the level of digital transformation of Italian hospitals. The focus on the Italian context is dictated, on the one hand, by the important efforts that the national government is making in order to ensure that digital health solutions integrate and improve the delivery models of existing health services, and on the other hand, by the strong disparity in the degree of digital transformation of healthcare structures due to the still heterogeneous implementation of regulatory interventions among the Italian regions (Odone et al., 2018). The strong commitment of the national government is demonstrated by interventions such as the "2014–2020 Strategy for Digital Growth" and the "2017–2019 Plan for Information Technology in Public Administration" which have provided a boost towards the digitalisation of the healthcare system through the introduction of electronic health records, telemedicine services and centralized health services booking systems (Odone et al., 2018). The strong disparity in the level of digital transformation between the different health facilities is instead demonstrated by the different choices of the Italian regions in relation to the adoption of electronic health records (Odone et al., 2018).

The reminder of this study is organized as follows: Section 2 presents the background of this study, while Section 3 introduces the research hypotheses. Section 4 describes the research design, while Section 5 and Section 6 respectively present and discuss the results. Finally, Section 7 draws conclusions.

2. Background

2.1. Digital transformation in healthcare

The concept of digital transformation is understood as the transition from structures that communicate through non-digital tools to structures that use digital tools. Digital transformation, however, does not represent the only technical process of converting information from paper to digital formats, but also requires a socio-technical change of digital tools and the way in which they are used (Yoo et al., 2010). To better understand this step, it is useful to analyse it from two different points of view (Preko and Boateng, 2020). The first is linked to a substantial split in the digitalisation process from a purely technical point of view and from a socio-technical point of view in which the of digital technologies and that of the people who have to use it is defined so that their respective contributions lead to the efficiency of the process (Sawyer and Jarrahi, 2014). The second concerns the material and social aspects of digitalisation that enable and force people to interact with digital tools to pursue the set objectives (Leonardi, 2013).

In the healthcare sector, the digital transformation of processes and services has become particularly relevant and popular and is gradually taking root both in local policies and in the strategic decisions of international healthcare organizations (Bara-Slupski, 2016; Preko and Boateng, 2020; Biancone et al., 2021). Digital technologies have played a central role in healthcare organizations since 1990 when the term 'e-health' was coined (Aceto et al., 2018; Tortorella et al., 2020a). The implementation of digital technologies within hospitals has increased more and more as they have become smaller, more accessible and capable of handling a greater amount of data (Ancarani et al., 2016; González et al., 2016; Tortorella et al., 2020a).

According to Tortorella et al. (2020b), academic studies on the topic of digital transformation in healthcare organizations have mainly examined three aspects: 1) the identification of the different digital technologies implemented; 2) the advantages and benefits deriving from the implementation of digital technologies; 3) the barriers and challenges associated with the implementation of digital technologies.

In relation to the first aspect, there seems to be no unanimous consensus regarding the digital technologies implemented within healthcare organizations. According to Tortorella et al. (2020b), academic studies have identified nine major digital technologies. Among these, biomedical/digital sensors and Cloud computing seem to be those cited by the largest number of academic studies (Garai et al., 2017; Zhang et al., 2017; Ali et al., 2018; Elhoseny et al., 2018; Hamidi, 2019; Munzer et al., 2019; Pace et al., 2019; Sannino et al., 2019), followed by the Internet of Things (Garai et al., 2017; Zhang et al., 2017; Elhoseny et al., 2018; Hamidi, 2019; Munzer et al., 2019; Pace et al., 2019; Sannino et al., 2019) and big data (Zhang et al., 2017; Elhoseny et al., 2018; Hamidi, 2019; Pace et al., 2019; Sannino et al., 2019). Other digital technologies recognized by academic studies are remote control or monitoring (Zhang et al., 2017; Hamidi, 2019; Pace et al., 2019), machine/deep learning (Zhang et al., 2017; Elhoseny et al., 2018; Hamidi, 2019), augmented reality/simulation (Zhang et al., 2017; Munzer et al., 2019), 3D printing (Zhang et al., 2017), and collaborative robots (Zhang et al., 2017). Such technologies, according to Tortorella et al. (2020b) were used both for health treatments and to support administrative processes.

In relation to the second aspect, academic studies have identified various advantages and benefits related to the implementation of digital technologies within healthcare organizations. In general, the implementation of digital solutions has increased the level of automation and

interconnectivity by improving the efficiency of patient care and administrative processes (Yang, 2015; Tortorella et al., 2020a, 2022). More in detail, a first benefit connected to the implementation of digital technologies in healthcare organizations is represented by the reduction of costs (e.g. Sakr and Elgammal, 2016; Aceto et al., 2018; Ali et al., 2018; Chen et al., 2018; Elhoseny et al., 2018; Wang et al., 2018; Amato et al., 2019; Munzer et al., 2019; Onasanya and Elshakankiri, 2021). Other important benefits are connected to an improvement in diagnosis and patient care (e.g. Aceto et al., 2018; Ali et al., 2018; Wang et al., 2018; Pace et al., 2019; Sannino et al., 2019), to greater personalization of health and real-time patient care (e.g. Garai et al., 2017; Thuemmler and Bai, 2017; Aceto et al., 2018; Ali et al., 2018; Pace et al., 2019; Sannino et al., 2019), to a reduction in waiting and delivery times (e.g. Ali et al., 2018; Pan et al., 2018; Wang et al., 2018; Pace et al., 2019; Munzer et al., 2019), to an improvement in collaborative health care (e.g. Guha & Kumar, 2018; Pan et al., 2018; Wang et al., 2018; Abdellatif et al., 2019; Albesher, 2019; Pace et al., 2019) and to an increased support for training and education (e.g. Guha & Kumar, 2018; Qi et al., 2018; Pan et al., 2018; Albesher, 2019; Munzer et al., 2019).

In relation to the third aspect, academic studies have identified a series of barriers and challenges related to the implementation of digital technologies in healthcare organizations. Among these, information security risks (e.g. Ali et al., 2018; Almulhim et al., 2019; Sannino et al., 2019; Pace et al., 2019; Wang et al., 2019), patents, price ceilings and lack of partnerships (e.g. Aceto et al., 2018; Ali et al., 2018; Pan et al., 2018; Hamidi, 2019; Munzer et al., 2019; Sannino et al., 2019), lack of information and communication technologies' skills (e.g. Ali et al., 2018; Manogaran et al., 2018; Mutlag et al., 2019; Pace et al., 2019; Wang et al., 2019) and implementation costs (e.g. Ali et al., 2018; Guha & Kumar, 2018; Pan et al., 2018; Hamidi, 2019; Pace et al., 2019; Wang et al., 2019) seem to represent the main obstacles. However, academic studies have also identified further barriers such as regulatory changes (e.g. Ali et al., 2018; Kumari et al., 2018; Hamidi, 2019), poor information and communication technologies infrastructure (e.g. Ali et al., 2018; Elhoseny et al., 2018; Guha & Kumar, 2018; Rajan & Rajan, 2018; Munzer et al., 2019), the misalignment between the adoption of digital technologies and the strategy of the healthcare organization (e.g. Almulhim et al., 2019; Hamidi, 2019; Sannino et al., 2019; Wang et al., 2019) and devices/systems heterogeneity (e.g. Guha & Kumar, 2018; Saxena and Raychoudhury, 2017; Abdellatif et al., 2019; Mutlag et al., 2019).

Going beyond the three aspects previously examined, another part of the studies analysed the factors that can influence the digital transformation of healthcare organizations. In this regard, Tortorella et al. (2020a), examining a sample of 16 hospitals located in Brazil, India, Mexico and Argentina, found that hospital's ownership and hospital functionality represent important drivers of the implementation of digital technologies with public hospitals and non-teaching hospitals that appear to be ahead of the private and teaching ones in digital transformation processes. According to the authors, the age of hospitals represents an additional factor that can influence the digital transformation. In fact, they have found a greater propensity towards the implementation of digital technologies by newer hospitals than older ones. Finally, the authors found conflicting results in relation to the impact of the hospital size on the degree of implementation of digital technologies by virtue of the different proxies used. Preko and Boateng (2020) on the other hand, examining the Ghanaian hospitals, have identified five generative mechanisms of digital transformation represented by standardization, financial transparency, storage systems, convergence and connectivity, and data security.

These studies represent the first attempts to examine the drivers of the implementation of digital technologies by healthcare organizations. However, there is a clear need for further empirical studies aimed at identifying additional drivers of the digital transformation of healthcare organizations and analysing this phenomenon also in other geographical contexts. This study aims to respond to these needs by analysing the effect of the hospitals' characteristics on the level of digital transformation in the Italian context.

2.2. The process towards the digital transformation of the Italian healthcare system

In Italy, the process towards the digital transformation of healthcare started several years ago. This slow process began, in the first period, with the digitization of document processes (electronic health records, online payments, digital prescriptions, etc.) and subsequently involved the introduction of other more complex and innovative digital technologies such as artificial intelligence, virtual reality, and cloud computing.

The first regulatory references in this direction were defined, at European level, by the Treaty on the Functioning of the European Union (Domenichiello, 2015). This concerned the responsibility of the Member States to define health policies for the organization of the provision of health services. Since 2000, the eEurope 2002 project aimed at enhancing the internet for electronic access to public services and specifically to health information. In 2004, the European Commission launched the first Action Plan for Europe on eHealth for the adoption of tools and services that use information and communication technologies for prevention, diagnosis, monitoring and management. This action plan was renewed in the following years to identify, in a strategic key, the use of these technologies as fundamental tools for the creation of effective and efficient public services in all member countries, especially in the health system (Domenichiello, 2015). However, each individual member country was able to define its own strategy to pursue these objectives (Domenichiello, 2015).

This circumstance makes it necessary to analyse the Italian context on the basis also of European guidelines. Since 2001, the institutional management system of the healthcare industry in Italy has changed, with a substantial reassignment of responsibilities to the Government and the Regions. Since 2004, the eHealth Board has been introduced which, together with the Regions, the Ministry of Health and the Ministry of Innovation and Public Administration, has the task of defining policies on eHealth issues and monitoring the implementation of the national and regional action plans. To date, the main activities carried out by the eHealth Board are the "Shared Policy for eHealth", which adopted the objectives of the European e-Health Action Plan 2004 and the "Architectural Strategy for e-Health", which constitutes a general guideline on the issues of national architecture design for e-Health. The areas of implementation most affected by the Board are: access to health services, availability of the patient's clinical history, innovation in primary care, redesign of the health services network through telemedicine (Domenichiello, 2015). Each region independently manages appointments for treatment through the Local health authorities and hospitals. Citizens can make reservations either directly at the hospital or through local unified booking centers. In 2008, a survey was carried out by the Ministry of Health aimed at showing the degree of diffusion of healthcare booking systems and electronic health record systems. A heterogeneous diffusion emerged at the level of the single region and this made it necessary, in 2010, to define national guidelines for the implementation of the healthcare booking systems. In 2011, on the other hand, guidelines were defined for the electronic health record systems which governed the summary information relating to the patient, the security of sensitive data for the purposes of protecting privacy. Furthermore, at the end of 2012 a law on electronic health record systems was definitively approved at national level (L.221 of 17/12/2012) which required the Regions and Autonomous Provinces to adopt these systems by June 30, 2015 (Domenichiello, 2015).

Since 2010, the transmission of sickness certificates has also been revolutionized. In fact, it is carried out online by doctors both to the employer and to the National Social Security Institute through technological infrastructures capable of transferring documents through regional gateways in full respect of privacy (Domenichiello, 2015).

Furthermore, in 2014 the guidelines governing telemedicine and the strategy with which it will be possible to place these services, models, processes and integration paths in clinical practice were defined. In order to strengthen the development of eHealth in Italy, other measures have been taken at a national level such as the online payment of health services and the telematic transmission of reports via the Web, certified e-mail or any other electronic means (Domenichiello, 2015).

After focusing the eHealth measures on the digitization of document processes in recent years, the "2014–2020 Strategy for Digital Growth" and the "2017–2019 Plan for Information Technology in Public Administration" have extended the focus also on the implementation of advanced digital technologies such as artificial intelligence and cloud computing in healthcare (Odone et al., 2018). However, the path towards a complete digital transformation of Italian healthcare system still seems long (Odone et al., 2018).

3. Theoretical background and hypotheses development

In line with other contributions on the topic (Tortorella et al., 2020a; Proksch et al., 2021), this study uses contingency theory to frame the digital transformation of hospitals. According to this theory, there is no single best way that leads to the success of organizations. According to Scott (1981, p. 114) "the best way to organize depends on the nature of the environment to which the organization must relate". In other words, the best way to manage organizations depends on internal and external contingencies (Shepard and Hougland, 1978; Donaldson, 2001). In particular, due to the complexity of healthcare systems, the management methods of organizations derive from external factors such as the culture and socio-economic context of the region, country and geographical area and from internal factors such as the characteristics and internal processes of individual organizations (Tortorella et al., 2020a). In relation to external factors, it is evident that elements such as the level of per capita income (Bedir, 2016) and the development of the local economy (Visconti et al., 2017) can influence the strategies and performance of healthcare organizations. Instead, in relation to internal factors, elements such as the number of beds and employees, functionality and age influence the dynamics of healthcare organizations (Kimberly and Evanisko, 1981; Sjetne et al., 2007; Theokary and Justin Ren, 2011; Moores, 2012; Zhang et al., 2017; Tortorella et al., 2020a).

This study focuses on the impact of internal factors on the level of digital transformation of hospitals. The impact of external factors was in fact mitigated by the focus on the Italian context alone, which leads to the exclusion of the effect of the socio-economic context at the region and country level. More in detail, this study examines the impact of the following characteristics of hospitals: size, complexity, age, and teaching status. The individual research hypotheses are developed below.

3.1. Hospital size

The size of the organizations, according to the academic literature, represents one of the main drivers of the adoption and implementation of new technologies (Bayo-Moriones and Lera-Lopez, 2007). In particular, academic contributions have provided several reasons why larger organizations are more likely to adopt and implement new digital solutions. Larger organizations enjoy greater capital and resources to be allocated to digital innovations (Hwang et al., 2004; Bayo-Moriones and Lera-Lopez, 2007). The greater availability of financial resources that distinguishes larger organizations not only allows greater investments in digital solutions but also increases the ability to absorb the risks associated with the uncertainty relating to the adoption and implementation of new digital technologies (Premkumar and Roberts, 1999). Larger organizations also have a greater chance of spreading fixed costs because of their larger scale of operations (Lind et al., 1989; Rahab and Hartono, 2012). Furthermore, in addition to having greater financial resources, they also enjoy greater human resources, sometimes even more qualified (Raimo et al., 2020). In light of this, there is a greater likelihood that within larger organizations there are human resources possessing digital skills capable of facilitating the adoption and implementation of digital solutions (Morgan et al., 2006). These reasons, valid for the different types of organizations, can also be considered sound for hospitals. In fact, academic literature has shown that larger hospitals enjoy greater financial resources and greater benefits deriving from economies of scale (Kimberly and Evanisko, 1981; Dewar and Dutton, 1986; Goldstein et al., 2002; Goldstein and Schweikhart, 2002). In addition, past studies have also pointed out that larger hospitals include more human resources, sometimes more qualified, not only in the medical but also in the information technology field (Yoon et al., 2016). In this regard, Alpar and Reeves (1990) highlighted the greater capacity of larger institutions to hire professionals such as technicians and physicians capable of promoting process innovation.

The reasons set out could also favour digital transformation processes. In this study, following Starkweather (1970), hospital size is expressed in number of beds. Therefore, in light of the above, it is possible to introduce the following hypothesis:

H1. Digital transformation is positively influenced by the number of hospital beds

3.2. Hospital complexity

The complexity of organizations, according to academic literature, represents another possible driver of the adoption and implementation of new technologies (Bayo-Moriones and Lera-Lopez, 2007). In fact, more complex organizations may have a greater need to innovate and digitalise processes (Salvi et al., 2021). These organizations have greater coordination problems due to the presence of units located in different places (Galliano et al., 2001) which leads to a greater need to digitalise the entire information flow (Dasgupta et al., 1999; Bayo-Moriones and Lera-Lopez, 2007; Arora and Rathi, 2019). In the context of hospitals, a broader functional differentiation increases the complexity of the hospital and the medical service offered (Damanpour, 1991; Young et al., 2001; Eiriz et al., 2010). According to Damanpour (1991), this functional differentiation strongly influences the adoption of innovative solutions. In fact, greater functional differentiation leads to a greater number of interest groups and a greater demand for technological solutions capable of further advancing the hospital's degree of innovation (Kimberly and Evanisko, 1981; Weng et al., 2011). Furthermore, according to Lo (2005), a more complex hospital enjoys greater resources and capabilities and is therefore able to improve its level of technological innovation. Finally, in relation to human resources, Damanpour (1996) and Yang (2015) underlined that in a more complex hospital there may be several specialists able to offer more diversified knowledge bases to improve the exchange and dissemination of creative ideas and the adoption of technological solutions.

The reasons set out could also favour digital transformation processes. In this study, hospital complexity is expressed in the number of departments (Capkun et al., 2012), and in terms of the presence of the emergency room. Therefore, in light of the above, it is possible to introduce the following hypotheses:

H2. Digital transformation is positively influenced by the number of hospital departments

H3. Digital transformation is positively influenced by the presence of the emergency room

3.3. Hospital age

The age of organizations, according to academic literature, represents another possible driver of the adoption and implementation of new technologies (Karshenas and Stoneman, 1995; Alderete and Gutiérrez, 2014). However, the theoretical arguments about the direction of the effect of the age of organizations on the degree of technological

innovation are not conclusive (Hollenstein, 2004). In fact, some studies argue that the age of organizations can favour the adoption and implementation of technologies (Karshenas and Stoneman, 1995; Alderete and Gutiérrez, 2014; Sebastian et al., 2017) while others argue that it can represent an obstacle in terms of resistance to change and experience in adopting advanced technologies (Dunne, 1994).

On the one hand, older organizations tend to enjoy a greater productive and functional knowledge base which can increase their capacity for innovation (Cohen and Levinthal, 1990). In this regards, older organizations have usually perfected the structures, incentive programs, routines and other infrastructures necessary for the adoption and implementation of new technologies (Sørensen and Stuart, 2000). They also usually face fewer financial constraints than younger organizations and therefore have greater potential for adoption and implementation of new technologies (OECD, 2019).

On the other hand, it has been argued that older organizations could potentially have additional difficulties as they may not have the sophisticated information and communication technology infrastructures necessary for the implementation of digital technologies (Garai et al., 2017; Zhang et al., 2017; Elhoseny et al., 2018). In this regard, younger organizations whose information and communication technology infrastructure has been designed and built more recently may have a more favourable environment for the adoption and implementation of digital technologies.

Despite the presence of conflicting opinions about the effect of the age of organizations on the degree of technological innovation, Tortorella et al. (2020a) showed a greater propensity towards the implementation of digital technologies by newer hospitals than older ones and therefore this circumstance leads us to prefer the theoretical arguments according to which age represents an obstacle to digital innovation.

In this study the hospital age, following Weng et al. (2011), is expressed in number of years. Therefore, in light of the above, it is possible to introduce the following hypothesis:

H4. Digital transformation is negatively influenced by the number of hospital years

3.4. Hospital teaching status

The teaching status of hospitals, according to academic literature, represents another possible driver of the adoption and implementation of new technologies (D'Sa et al., 1994; Weng et al., 2011). There are important differences between teaching and non-teaching hospitals by virtue of the different educational and health care roles (D'Sa et al., 1994). Teaching hospitals offer their facilities to doctors, health personnel and medical students for medical training and education (Weng et al., 2006). These hospitals therefore provide higher level teaching and are more research-oriented (Weng et al., 2011). The greater focus on research increases the absorptive capacity (Cohen and Levinthal, 1990) of teaching hospitals which in turn enriches the technological knowledge resources (Chen, 2004). This technological knowledge allows a better understanding of the technologies and procedures for their implementation (Damanpour, 1991), favouring the innovation of teaching hospitals (Keller, 1996). Furthermore, the presence of specialized personnel with specific knowledge able to use new technologies allows teaching hospitals to obtain greater cost efficiency, thus favouring innovation processes (D'Sa et al., 1994). Furthermore, teaching hospitals may have a greater need to innovate processes and adopt new technological solutions due to the greater spectrum of clinical problems than non-teaching hospitals (D'Sa et al., 1994). Finally, teaching hospitals usually enjoy greater resources to be allocated to the adoption and implementation of new technologies (D'Sa et al., 1994). In this regard, Weng et al. (2011) highlighted that teaching hospitals are much more technological than non-teaching ones.

The reasons set out could also favour digital transformation processes. In this study, the hospital teaching status, following Weng et al. (2011), is expressed in terms of affiliation with the university. Therefore, in light of the above, it is possible to introduce the following hypothesis:

H5. Digital transformation is positively influenced by hospital/university affiliation

4. Research design

The empirical analysis conducted in this study is based on data collected through a questionnaire aimed at examining the level of digital transformation of Italian hospitals. This questionnaire was sent to the different Italian hospitals, selected from the list of hospital facilities provided by the Italian National Health Service. The questionnaire was administered in the period ranging from May to June 2021. The choice of short times eliminates the possible anomalies that could derive from the administration of the questionnaire in very long periods. As regards the method of sending, it was preferred to use e-mail and therefore forward the questionnaire to the address indicated on the official website of the hospital. In addition, to maximize the response rate, a telephone appointment was also set with the hospitals in order to inform them about the purpose of the research and to assure them of the anonymity of the data collected. This circumstance allowed us to obtain a good response rate to the questionnaire also taking into account the difficult period experienced by hospitals due to the spread of the COVID-19 pandemic.

Following Tortorella et al. (2020a), we addressed the questionnaire to subjects holding key leadership roles (senior or middle management) within the hospital. The administration of the questionnaire to these subjects ensured adequate validity of the answers considering that the senior or middle management should be fully aware of the dynamics of the hospital and its specificities also in relation to digital transformation. Furthermore, in order to increase the reliability and internal validity of the study, mitigating the issues connected to single respondent bias (Brewer and Crano, 2000; Tabachnick et al., 2007; Hair et al., 2014; Tortorella et al., 2020a), we requested a second answer to the questionnaire from subjects operating in the information and communication technology department. The administration of the questionnaire to these subjects has in fact further increased the validity of the answers considering that they should have specific knowledge about the implementation of digital technologies by the hospital. The comparison of the results of the questionnaires completed by the senior or middle management and by the subjects operating in the information and communication technology department confirmed a high reliability of the answers.

The final sample on which the econometric analysis is conducted includes the 103 Italian hospitals that responded to the questionnaire. These hospitals present an adequate differentiation in terms of size, complexity, ownership and geographical location.

In order to test the research hypotheses, this study uses an ordinary least squares (OLS) regression model, based on the variables described below.

The dependent variable of this study is represented by the digital transformation level (DTL) of Italian hospitals. It was measured through the use of a questionnaire based on 18 elements corresponding to as many different digital health technologies (summarized in Table 1). The consideration of different elements is supported by the academic literature (Salvi et al., 2021) which suggests the impossibility of describing a large and complex phenomenon such as digital transformation through a single item. For the identification of the elements concerning the digital transformation of hospitals, an important professional document drawn up by Deloitte (2020) was used. This document precisely identifies 18 different types of digital health technologies that can be implemented in hospitals. Within the questionnaire, a question was provided for each digital technology, which can be evaluated through a scale ranged from 0 to 5. This scale aims at an in-depth evaluation of the use of the different digital health technologies with 0 corresponding to an absence of the

Table 1
Digital health technologies.

1	Electronic health record
2	Digital prescribing systems
3	Online appointment booking
4	Apps for Clinicians
5	Online access platforms/tools
6	Telemedicine
7	Digital rostering systems
8	Automation of pharmacy dispensing systems
9	Point of care diagnostics
10	Patients Apps/Wearables
11	Remote vital sign monitoring
12	Automation of other clinical tasks
13	Voice recognition tools
14	Robotics
15	Digital platforms for genomics data analysis
16	Radio Frequency Identification tags
17	Artificial Intelligence technologies
18	Virtual reality

specific digital solution and 5 which corresponds to a continuous and total use. Within the questionnaire, the same weight was assigned to each digital health technology. This choice derives from the desire to assign the same importance to each digital health technology without identifying more important digital solutions for hospitals. Thus, in light of this, the dependent variable of this study can range from 0 to 90.

In order to ensure content validity, the set of digital health technologies and the entire questionnaire were reviewed by a group of six well-informed experts on the topic of the digital transformation of hospitals. Three of them have in fact held the position of general manager in Italian hospitals, one holds a top position in an Italian local health board, while the other two experts hold an executive master in digital health transformation. These experts examined the formulation of the questions and the possible need to include additional questions related to additional digital solutions that can be implemented in hospitals. Unanimously they agreed on the correct formulation of the questions and the completeness of the survey, thus excluding the possibility of including further questions.

The independent variables of this study are: hospital size, hospital complexity, hospital age and hospital teaching status. Hospital size, following Starkweather (1970), was measured through the natural logarithm of the number of beds in the hospital (HBEDS). Hospital complexity provides for two different operationalizations. A first operationalization in fact, following Capkun et al. (2012), concerns the number of departments of the hospital (HDEP). A second operationalization concerns the presence of the emergency room inside the hospital (ER). This variable has a dichotomous nature and assumes a value of 1 if the hospital provides for the presence of an emergency room and a value of 0 in the opposite case. Hospital age, following Weng et al. (2011), was calculated as the number of years since the founding of the hospital (HYEARS). Finally, hospital teaching status, following Weng et al. (2011), considers the existence of a hospital/university affiliation (HUA). This variable has a dichotomous variable and takes on a value of 1 if the hospital is affiliated with a university and a value of 0 in the opposite case. The data relating to the independent variables were collected directly through the websites of the individual hospitals.

In order to increase the goodness of the econometric model, some control variables have been included. In particular, the following control variables have been added: internet visibility, general manager gender, general manager age and geographical location. Internet visibility concerns the attention dedicated on the web (in particular on Google) by users towards the hospital and was calculated as the natural logarithm of the results of a search in "google.com" in which the exact name of the hospital appears (GVIS). General manager gender assumes a score of 1 if the hospital is led by a female general manager (FEMGM), and 0 otherwise (Cumming et al., 2015). General manager age was calculated using the years of the hospital general manager (GMYEARS). Finally, geographical location assumes a score of 1 if the hospital is located in northern Italy (NORTH), and 0 otherwise.

The analysis model proposed by this study is reflected in the following equation:

$$DTL = \beta_0 + \beta_1 HBEDS + \beta_2 HDEP + \beta_3 ER + \beta_4 HYEARS + \beta_5 HUA + \beta_6 GVIS + \beta_7 FEMGM + \beta_8 GMYEARS + \beta_9 NORTH + \varepsilon$$

5. Results

Table 2 presents the descriptive statistics, the variance inflation factor (VIF) analysis and the correlation matrix. As far as descriptive statistics are concerned, an important result is represented by the mean of the level of digital transformation of the hospitals included in the sample. In fact, it has a value of 38.95 which demonstrates a low degree of adoption and use of digital technologies in the Italian hospitals examined. This result demonstrates the need for further efforts by Italian hospitals towards digital transformation. Regarding the independent variables, the hospitals in the sample on average include about 31 departments. Furthermore, about 91% of them include the emergency room, while about 32% have an affiliation with a university. Finally, the hospitals included in the sample have an average age of about 74 years.

The VIF analysis allows to exclude multicollinearity problems. VIFs in fact vary from a minimum of 1.30 to a maximum of 2.61. In this regard, according to Myers (1990), multicollinearity problems are recorded only in the presence of values greater than 10. The absence of multicollinearity is also supported by the correlation analysis presented in the second part of Table 2. The highest correlation coefficient is in fact equal to 0.561 and, according to Farrar and Glauber (1967) and Kennedy (1999), multicollinearity issues exist only in the presence of values that exceed ± 0.8 or ± 0.9. In light of this, it is possible to state that there are no multicollinearity problems in the interpretation of the results of the regression analysis.

Results of the OLS regression analysis with robust standard errors are presented in Table 3. The adjusted R^2 shows a good ability of the econometric model to explain the variability of the dependent variable. In fact, it has a value of 0.484. The research hypotheses are only partially supported by the results of the regression analysis.

As regards the impact of the hospital size, the results confirm hypothesis 1 (H1) and show a positive and significant relationship between the number of hospital beds and the level of digital transformation at $p = 0.002$. This result demonstrates a greater propensity of larger hospitals to undertake digital transformation processes.

As regards the impact of hospital complexity, the results are conflicting. In fact, they support hypothesis 3 (H3) but do not support hypothesis 2 (H2). More specifically, they show a positive and significant relationship between the presence of the emergency room and the level of digital transformation at $p = 0.049$ and a non-significant relationship between the number of departments and the level of digital transformation. These results show that the existence of an emergency room represents a push towards the digital transformation process, while the number of departments does not significantly influence the adoption of digital solutions.

As regards the impact of hospital age, the results do not confirm hypothesis 4 (H4) showing a positive and significant relationship between the hospital years and the level of digital transformation at $p = 0.058$. This result, contrary to expectations, demonstrates a greater propensity of longer-lived hospitals to undertake digital transformation processes.

Finally, as regards the impact of hospital teaching status, the results confirm hypothesis 5 (H5) and show a positive and significant relationship between the hospital's affiliation with a university and the level of digital transformation at $p = 0.005$. This result demonstrates a greater propensity for hospitals that have an affiliation with a university to undertake digital transformation processes.

Table 2
Descriptive statistics, VIFs and correlation analysis.

Variables	Mean	S.D.	VIF	DTL		HBEDS		HDEP		ER		HYEARS		HUA		GVIS		FEMGM		GMYEARS		NORTH
DTL	38.95	14.02		1																		
HBEDS	5.60	1.27	2.61	0.502	***	1																
HDEP	31.36	27.34	2.08	0.387	***	0.561	***	1														
ER	0.91	0.28	1.31	0.415	***	0.372	***	0.242	**	1												
HYEARS	73.91	132.89	1.30	0.347	***	0.265	**	0.338	***	0.095		1										
HUA	0.32	0.46	1.69	0.492	***	0.536	***	0.435	***	0.138	***	0.406	***	1								
GVIS	11.31	1.77	1.36	0.378	***	0.350	***	0.111		0.346	***	−0.010		0.140		1						
FEMGM	0.07	0.18	1.64	0.087		0.128		0.091		0.142		−0.036		−0.042		−0.034		1				
GMYEARS	53.74	8.82	1.72	0.031		−0.005		0.089	**	0.034		0.164	*	0.150		0.163		−0.546	***	1		
NORTH	0.44	0.49	1.40	0.270	***	0.124		0.239	**	0.278	***	0.120		−0.072		0.197	**	0.306	***	0.041		1

Note: $n = 103$. S.D. = Standard Deviation. *** = significant at the 1% level; ** = significant at the 5% level; * = significant at the 10% level.

Table 3
Regression model results.

Variables	Baseline Model		Complete Model	
	β (SE)	p-value	β (SE)	p-value
HBEDS			4.012 (1.263)	0.002[c]
HDEP			−0.057 (0.052)	0.276
ER			7.937 (4.022)	0.049[b]
HYEARS			0.016 (0.008)	0.058[a]
HUA			7.977 (2.768)	0.005[c]
GVIS	1.462 (0.642)	0.076[a]	1.148 (0.657)	0.084[a]
FEMGM	−2.791 (3.516)	0.373	−2.353 (3.430)	0.494
GMYEARS	−0.168 (0.136)	0.283	−0.151 (0.144)	0.299
NORTH	6.894 (2.375)	0.014[b]	5.694 (2.366)	0.018[b]
Cons	0.412 (0.277)	0.000[c]	0.450 (0.351)	0.000[c]
N	103		103	
Adj R^2	0.274		0.484	

[a] Significant at the 10% level.
[b] Significant at the 5% level.
[c] Significant at the 1% level.

6. Discussion

The results obtained demonstrate the relevance of the hospitals' characteristics in digital transformation processes. In particular, they show a positive and significant impact of the size, age and teaching status of hospitals and a partial positive effect of hospital complexity (connected only to the presence of the emergency room) on the level of digital transformation. In a contingency theory key, these elements represent the internal factors capable of influencing the digital transformation policies and strategies of Italian hospitals. Moving on to a more detailed analysis of the results obtained, this study first of all demonstrates a strong positive influence of the size of hospitals on the degree of digital transformation. This result can be explained, on the one hand, by the greater financial resources enjoyed by larger hospitals and by the greater advantages deriving from economies of scale (Kimberly and Evanisko, 1981; Dewar and Dutton, 1986; Goldstein et al., 2002; Goldstein and Schweikhart, 2002) and, on the other hand, by the availability of more qualified human resources also in possession of digital skills (Yoon et al., 2016). These elements are in fact able to facilitate the adoption and implementation of digital technologies within hospitals. The results obtained in relation to the impact of the hospital size on the degree of digital transformation clarify what was found in the study by Tortorella et al. (2020a) which by examining the emerging economies had obtained conflicting results by virtue of the different proxies used.

The results are instead contrasting in relation to the impact of hospital complexity on the degree of digital transformation. In fact, on the one hand they demonstrate a positive impact of the presence of the emergency room and, on the other hand, they demonstrate a non-significant effect of the number of departments. The positive impact of the presence of the emergency room on the degree of digital transformation can be explained by the need to digitalise the processes resulting from the provision of first aid by the hospitals (Heldt et al., 2021). In fact, the presence of an emergency room requires digital solutions both to speed up the entry processes of new patients and to improve the care provided and the tracking of healthcare traces carried out. In addition, the positive effect of the presence of the emergency room on the degree of digital transformation can also be explained by the greater availability of monetary resources available to hospitals that include this department. The non-significant effect of the number of departments on the level of digital transformation is a surprising result which, however, can be explained by the low need in some specific departments to adopt digital solutions. The results obtained in relation to the impact of hospital complexity on the degree of digital transformation provide an important contribution to the academic literature since to the best of our knowledge, no previous study had examined the impact of this variable.

This study also demonstrates a positive impact of hospital age on the degree of digital transformation. Although this is a contrary result compared to expectations, it can still be explained, on the one hand, by the availability of a well-defined resource base by the older hospitals to be allocated to digitalisation and, on the other hand, by the greater propensity of these hospitals to adopt digital technologies in order to insuring their status in the reference community (Kimberly and Evanisko, 1981). The results obtained in relation to the impact of hospital age on the degree of digital transformation are contrary to what was found by Tortorella et al. (2020a) through a study conducted on emerging economies.

Finally, this study demonstrates a positive impact of hospital teaching status on the degree of digital transformation. This result can be explained, on the one hand, by the greater digital knowledge of teaching hospitals staff, connected to the focus on research (Weng et al., 2006, 2011), and, on the other hand, by the greater need for such hospitals to digitalise processes due to the greater spectrum of clinical problems (D'Sa et al., 1994). In addition, a further explanation may be related to the greater availability of monetary resources by teaching hospitals to be also allocated to the adoption and implementation of digital solutions (D'Sa et al., 1994). The results obtained in relation to the impact of hospital teaching status on the degree of digital transformation are contrary to what was found by Tortorella et al. (2020a) through a study conducted on emerging economies.

The results of this study, in part contrary to what was found by Tortorella et al. (2020a), further confirm the goodness of contingency theory as a theoretical perspective to frame the digital transformation of hospitals. The dynamics relating to the digital transformation of healthcare organizations, according to the contingency theory, are the result not only of internal factors such as the characteristics of hospitals but also of external factors such as the culture and socio-economic context of the country. In light of this, it is therefore possible to obtain different results in different geographical contexts.

7. Conclusions

This study aimed to analyse the level of digital transformation of Italian hospitals and the factors that can affect this level of digital transformation. In particular, in the context of the different types of determinants, this study aimed to examine the impact of hospitals' characteristics on the level of digital transformation. The results show a full relevance of the size, age and teaching status of hospitals and a partial importance of hospital complexity in digital transformation processes. More specifically, the results showed a positive impact of the number of beds, presence of the emergency room, age, and affiliation with a university on the level of digital transformation of Italian hospitals. In addition, they showed a non-significant effect of the number of departments on the adoption and implementation of digital solutions by Italian hospitals.

This study contributes to enriching academic literature in different ways. Firstly, it provides a new methodology for measuring the level of digital transformation of hospitals that can be used by future research. Secondly, it extends the field of application of contingency theory which is still little used to explain the dynamics connected to the digital transformation of healthcare organizations. Third, this study provides information on the effective use of digital technologies by Italian hospitals. Finally, this study contributes to the knowledge of the drivers of the adoption and implementation of digital solutions by healthcare organizations, showing the role played by the hospitals' characteristics.

The results obtained also offer important implications for policy makers. In recent years, the growth rate of the digitalisation of some aspects of health care has increased significantly, also driven by the spread of the COVID-19 pandemic. However, this study demonstrated the need for further efforts to achieve full and complete digitalisation of health services. In light of this, policy makers should encourage the digital transformation of hospitals through specific regulations and a new approach to funding ground on value-based outcomes in order to ensure an efficient and cost-effective future with a focus on prevention, reduction of health inequalities and on improving the health and well-being of the population. In this perspective, encouraging digital transformation and the adoption and implementation of digital technologies could guarantee the healthcare system a preventive, predictive, participatory and personalized future. To this end, policy makers should also pay attention to citizens' digital skills in order to support a wider spread of digital health technologies. In fact, the adoption and implementation of specific digital technologies to access health care such as online appointment booking, virtual health consultancy and apps to manage health remotely could be useless in the presence of citizens with little digital knowledge. Bridging the gap in digital health literacy is particularly relevant also because digital knowledge gaps usually concern those (for example, elderly people) who are in greatest need of health care.

However, this study is not without limitations. The main limitation is related to the sample size which includes only 103 Italian hospitals. However, this limitation does not reduce the overall quality of this study and offers important insights for future research. In fact, they will be able to extend the sample size using different methods for sending the questionnaire to Italian hospitals. Furthermore, future research will be able to replicate this study in the coming years in order to verify the effective push provided by the COVID-19 pandemic to the digital transformation processes of Italian hospitals. Finally, future studies will be able to extend the analysis to hospitals located in other countries of the world in order to make comparisons of the level of digital transformation between Italian and foreign hospitals.

References

Abdellatif, A.A., Mohamed, A., Chiasserini, C.F., Tlili, M., Erbad, A., 2019. Edge computing for smart health: context-aware approaches, opportunities, and challenges. IEEE Network 33 (3), 196–203.

Aceto, G., Persico, V., Pescapé, A., 2018. The role of Information and Communication Technologies in healthcare: taxonomies, perspectives, and challenges. Journal of Network and Computer Applications 107, 125–154.

Agarwal, R., Guodong, G., DesRoches, C., Jha, A.K., 2010. The digital transformation of healthcare: current status and the road ahead. Information Systems Research 21 (4), 796–809.

Albesher, A.A., 2019. Iot in health-care: recent advances in the development of smart cyber-physical ubiquitous environments. International Journal of Computer Science and Network Security 19 (2), 181.

Alderete, M.V., Gutiérrez, L.H., 2014. Drivers of information and communication technologies adoption in Colombian services firms. International Journal of Business Information Systems 17 (4), 373–397.

Ali, O., Shrestha, A., Soar, J., Wamba, S.F., 2018. Cloud computing-enabled healthcare opportunities, issues, and applications: a systematic review. International Journal of Information Management 43, 146–158.

Almulhim, M., Islam, N., Zaman, N., 2019. A lightweight and secure authentication scheme for IoT based e-health applications. International Journal of Computer Science and Network Security 19 (1), 107–120.

Alpar, P., Reeves, S., 1990. Predictors of MS/OR application in small businesses. Interfaces 20 (2), 2–11.

Amato, F., Marrone, S., Moscato, V., Piantadosi, G., Picariello, A., Sansone, C., 2019. HOLMeS: EHealth in the big data and deep learning era. Information 10 (2), 34.

Ancarani, A., Di Mauro, C., Gitto, S., Mancuso, P., Ayach, A., 2016. Technology acquisition and efficiency in Dubai hospitals. Technological Forecasting and Social Change 113, 475–485.

Arora, A.K., Rathi, P., 2019. An analysis of implementation of digitalisation in SMEs in India. International Journal of Online Marketing 9 (3), 70–81.

Avison, D., Young, T., 2007. Time to rethink health care and ICT? Communications of the ACM 50 (6), 69–74.

Bara-Slupski, T.K., 2016. Holistic Approach: paradigm shift in the research agenda for digitalisation of healthcare in Sub-Saharan Africa. The African Journal of Information Systems 8 (4), 3.

Bayo-Moriones, A., Lera-López, F., 2007. A firm-level analysis of determinants of ICT adoption in Spain. Technovation 27 (6–7), 352–366.

Bedir, S., 2016. Healthcare expenditure and economic growth in developing countries. Advances in Economics and Business 4 (2), 76–86.

Biancone, P., Secinaro, S., Marseglia, R., Calandra, D., 2021. E-health for the future. Managerial perspectives using a multiple case study approach. Technovation, 102406.

Brewer, M.B., Crano, W.D., 2000. Research design and issues of validity. Handbook of Research Methods in Social and Personality Psychology 3–16.

Capkun, V., Messner, M., Rissbacher, C., 2012. Service specialization and operational performance in hospitals. International Journal of Operations & Production Management 32 (4), 468–495.
Car, J., Anandan, C., Black, A., Cresswell, K., Pagliari, C., McKinstry, B., Procter, R., Majeed, A., Sheikh, A., 2008. The Impact of eHealth on the Quality & Safety of Healthcare – A Systematic Overview and Synthesis of the Literature, Report. NHS Connecting for Health Evaluation Programme.
Cerchione, R., Centobelli, P., Riccio, E., Abbate, S., Oropallo, E., 2022. Blockchain's coming to hospital to digitalize healthcare services: designing a distributed electronic health record ecosystem. Technovation, 102480.
Chen, M., Li, W., Hao, Y., Qian, Y., Humar, I., 2018. Edge cognitive computing based smart healthcare system. Future Generation Computer Systems 86, 403–411.
Chen, C.J., 2004. The effects of knowledge attribute, alliance characteristics, and absorptive capacity on knowledge transfer performance. R&D Management 34 (3), 311–321.
Cobianchi, L., Dal Mas, F., Peloso, A., Pugliese, L., Massaro, M., Bagnoli, C., Angelos, P., 2020a. Planning the full recovery phase: an antifragile perspective on surgery after COVID-19. Annals of Surgery 272 (6), e296–e299.
Cobianchi, L., Pugliese, L., Peloso, A., Dal Mas, F., Angelos, P., 2020b. To a new normal: surgery and COVID-19 during the transition phase. Annals of Surgery 272 (2), e49–e51.
Cohen, B., Amorós, J.E., Lundy, L., 2017. The generative potential of emerging technology to support startups and new ecosystems. Business Horizons 60 (6), 741–745.
Cohen, W.M., Levinthal, D.A., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 128–152.
Cumming, D., Leung, T.Y., Rui, O., 2015. Gender diversity and securities fraud. Academy of Management Journal 58 (5), 1572–1593.
D'Sa, M.M., Hill, D.S., Stratton, T.P., 1994. Diffusion of innovation I: formulary acceptance rates of new drugs in teaching and non-teaching British Columbia hospitals-A hospital pharmacy perspective. The Canadian Journal of Hospital Pharmacy 47 (6), 254–260.
Damanpour, F., 1991. Organizational innovation: a meta-analysis of effects of determinants and moderators. Academy of Management Journal 34 (3), 555–590.
Damanpour, F., 1996. Organizational complexity and innovation: developing and testing multiple contingency models. Management Science 42 (5), 693–716.
Dasgupta, S., Agarwal, D., Ioannidis, A., Gopalakrishnan, S., 1999. Determinants of information technology adoption: an extension of existing models to firms in a developing country. Journal of Global Information Management 7 (3), 30–40.
Deloitte, 2020. Digital Transformation: Shaping the Future of European Healthcare. Retrieved from. https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/life-sciences-health-care/deloitte-uk-shaping-the-future-of-european-healthcare.pdf.
Dewar, R.D., Dutton, J.E., 1986. The adoption of radical and incremental innovations: an empirical analysis. Management Science 32 (11), 1422–1433.
Domenichiello, M., 2015. State of the art in adoption of e-Health services in Italy in the context of European Union E-Government strategies. Procedia Economics and Finance 23, 1110–1118.
Donaldson, L., 2001. The Contingency Theory of Organizations. Sage, Thousand Oaks.
Drago, C., Gatto, A., Ruggeri, M., 2021. Telemedicine as technoinnovation to tackle COVID-19: a bibliometric analysis. Technovation, 102417.
Dunne, T., 1994. Plant age and technology use in US manufacturing industries. The RAND Journal of Economics 25 (3), 488–499.
Eiriz, V., Barbosa, N., Figueiredo, J., 2010. A conceptual framework to analyse hospital competitiveness. The Service Industries Journal 30 (3), 437–448.
Elhoseny, M., Abdelaziz, A., Salama, A.S., Riad, A.M., Muhammad, K., Sangaiah, A.K., 2018. A hybrid model of internet of things and cloud computing to manage big data in health services applications. Future Generation Computer Systems 86, 1383–1394.
Elia, G., Margherita, A., Passiante, G., 2020. Digital entrepreneurship ecosystem: how digital technologies and collective intelligence are reshaping the entrepreneurial process. Technological Forecasting and Social Change 150, 119791.
Farrar, D.E., Glauber, R.R., 1967. Multicollinearity in regression analysis: the problem revisited. The Review of Economic and Statistics 49 (1), 92–107.
Galliano, D., Roux, P., Filippi, M., 2001. Organisational and spatial determinants of ICT adoption: the case of French industrial firms. Environment and Planning A 33 (9), 1643–1663.
Garai, Á., Péntek, I., Adamkó, A., Németh, Á., 2017. A clinical system integration methodology for bio-sensory technology with cloud architecture. Acta Cybernetica 23 (2), 513–536.
Goldstein, S.M., Schweikhart, S.B., 2002. Empirical support for the Baldrige Award framework in US hospitals. Health Care Management Review 27 (1), 62–75.
Goldstein, S.M., Ward, P.T., Leong, G.K., Butler, T.W., 2002. The effect of location, strategy, and operations technology on hospital performance. Journal of Operations Management 20 (1), 63–75.
González, L.P., Jaedicke, C., Schubert, J., Stantchev, V., 2016. Fog computing architectures for healthcare: wireless performance and semantic opportunities. Journal of Information, Communication and Ethics in Society 14 (4), 334–349.
Guha, S., Kumar, S., 2018. Emergence of big data research in operations management, information systems, and healthcare: past contributions and future roadmap. Production and Operations Management 27 (9), 1724–1735.
Hair, J., Black, W., Babin, B., Anderson, R., 2014. Multivariate Data Analysis. Pearson New International Edition, Harlow, Essex. Pearson.
Hamidi, H., 2019. An approach to develop the smart health using Internet of Things and authentication based on biometric technology. Future Generation Computer Systems 91, 434–449.
Heldt, F.S., Vizcaychipi, M.P., Peacock, S., Cinelli, M., McLachlan, L., Andreotti, F., et al., 2021. Early risk assessment for COVID-19 patients from emergency department data using machine learning. Scientific Reports 11 (1), 1–13.
Hollenstein, H., 2004. Determinants of the adoption of Information and Communication Technologies (ICT): an empirical analysis based on firm-level data for the Swiss business sector. Structural change and economic dynamics 15 (3), 315–342.
Hwang, H.G., Ku, C.Y., Yen, D.C., Cheng, C.C., 2004. Critical factors influencing the adoption of data warehouse technology: a study of the banking industry in Taiwan. Decision Support Systems 37 (1), 1–21.
Karshenas, M., Stoneman, P., 1995. Technological diffusion. In: Stoneman, P. (Ed.), Handbook of the Economics of Innovation and Technological Change. Blackwell, Oxford, pp. 265–297.
Keller, W., 1996. Absorptive capacity: on the creation and acquisition of technology in development. Journal of Development Economics 49 (1), 199–227.
Kennedy, P., 1999. A Guide to Econometrics, fourth ed. Blackwell Publishers, Oxford.
Kimberly, J.R., Evanisko, M.J., 1981. Organizational innovation: the influence of individual, organizational, and contextual factors on hospital adoption of technological and administrative innovations. Academy of Management Journal 24 (4), 689–713.
Kraus, S., Schiavone, F., Pluzhnikova, A., Invernizzi, A.C., 2021. Digital transformation in healthcare: analyzing the current state-of-research. Journal of Business Research 123, 557–567.
Kumari, A., Tanwar, S., Tyagi, S., Kumar, N., 2018. Fog computing for Healthcare 4.0 environment: opportunities and challenges. Computers & Electrical Engineering 72, 1–13.
Leonardi, P.M., 2013. Theoretical foundations for the study of sociomateriality. Information and Organization 23 (2), 59–76.
Lind, M.R., Zmud, R.W., Fischer, W.A., 1989. Microcomputer adoption—the impact of organizational size and structure. Information & Management 16 (3), 157–162.
Lo, H., 2005. Antecedents and consequences of the adoption and expansion of new medical technology in hospitals. Taiwan Journal of Public Health 25 (5), 385–391.
Locatelli, P., Restifo, N., Gastaldi, L., Corso, M., 2012. Health Care Information Systems: Architectural Models and Governance. Innovative Information Systems Modelling and Techniques, pp. 71–96.
Locatelli, P., Restifo, N., Gastaldi, L., Sini, E., Torresani, M., 2010. The evolution of hospital information systems and the role of electronic patient records: from the Italian scenario to a real case. In: MEDINFO 2010 MEDINFO 2010 – Proceedings of the 13th World Congress on Medical Informatics (Studies in Health Technology and Informatics, vol. 160. IOS Press, Amsterdam, pp. 247–251.
Lorenzi, N.M., Novak, L.L., Weiss, J.B., Gadd, C.S., Unertl, K.M., 2008. Crossing the implementation chasm: a proposal for bold action. Journal of the American Medical Informatics Association 15 (3), 290–296.
Madhavan, N., White, G.R., Jones, P., 2021. Identifying the value of a clinical information system during the COVID-19 pandemic. Technovation, 102446.
Manogaran, G., Varatharajan, R., Lopez, D., Kumar, P.M., Sundarasekar, R., Thota, C., 2018. A new architecture of Internet of Things and big data ecosystem for secured smart healthcare monitoring and alerting system. Future Generation Computer Systems 82, 375–387.
Marques, I.C., Ferreira, J.J., 2020. Digital transformation in the area of health: systematic review of 45 years of evolution. Health and Technology 10, 575–586.
Massaro, M., 2021. Digital transformation in the healthcare sector through blockchain technology. Insights from academic research and business developments. Technovation, 102386.
Mihailescu, M., Mihailescu, D., 2018. January). The emergence of digitalisation in the context of health care. In: Proceedings of the 51st Hawaii International Conference on System Sciences, pp. 3063–3071.
Moores, T.T., 2012. Towards an integrated model of IT acceptance in healthcare. Decision Support Systems 53 (3), 507–516.
Morgan, A., Colebourne, D., Thomas, B., 2006. The development of ICT advisors for SME businesses: an innovative approach. Technovation 26 (8), 980–987.
Munzer, B.W., Khan, M.M., Shipman, B., Mahajan, P., 2019. Augmented reality in emergency medicine: a scoping review. Journal of Medical Internet research 21 (4), e12368.
Mutlag, A.A., Abd Ghani, M.K., Arunkumar, N.A., Mohammed, M.A., Mohd, O., 2019. Enabling technologies for fog computing in healthcare IoT systems. Future Generation Computer Systems 90, 62–78.
Myers, R.H., 1990. Classical and Modern Regression with Applications, second ed. Duxbury Press, Belmont, CA.
Nambisan, S., 2017. Digital entrepreneurship: toward a digital technology perspective of entrepreneurship. Entrepreneurship theory and Practice 41 (6), 1029–1055.
Odone, A., Signorelli, C., Zoli, A., 2018. Digitalization of healthcare in Italy: state of the art and best practices. European Journal of Public Health 28 (Suppl. l_4), 213–214.
OECD, 2019. Measuring the digital transformation: a roadmap for the future. Available at: https://www.oecd-ilibrary.org/science-and-technology/measuring-the-digital-transformation_9789264311992-en.
Or, C., Dohan, M., Tan, J., 2014. Understanding critical barriers to implementing a clinical information system in a nursing home through the lens of a socio-technical perspective. Journal of Medical Systems 38 (9), 1–10.
Onasanya, A., Elshakankiri, M., 2021. Smart integrated IoT healthcare system for cancer care. Wireless Networks 27 (6), 4297–4312.
Pace, P., Aloi, G., Gravina, R., Caliciuri, G., Fortino, G., Liotta, A., 2019. An edge-based architecture to support efficient applications for healthcare industry 4.0. IEEE Transactions on Industrial Informatics 15 (1), 481–489.
Pan, J., Ding, S., Wu, D., Yang, S., Yang, J., 2018. Exploring behavioural intentions toward smart healthcare services among medical practitioners: a technology transfer perspective. International Journal of Production Research 57 (18), 5801–5820.

Preko, M., Boateng, R., 2020. Assessing healthcare digitalisation in Ghana: a critical realist's approach. Health Policy and Technology 9 (2), 255–262.
Premkumar, G., Roberts, M., 1999. Adoption of new information technologies in rural small businesses. Omega 27 (4), 467–484.
Proksch, D., Rosin, A.F., Stubner, S., Pinkwart, A., 2021. The influence of a digital strategy on the digitalization of new ventures: the mediating effect of digital capabilities and a digital culture. Journal of Small Business Management 1–29.
Qi, J., Yang, P., Waraich, A., Deng, Z., Zhao, Y., Yang, Y., 2018. Examining sensor-based physical activity recognition and monitoring for healthcare using Internet of Things: a systematic review. Journal of Biomedical Informatics 87, 138–153.
Rahab, Hartono, J., 2012. Adoption of information technology on small businesses: the role of environment, organizational and leader determinant. International Journal of Business, Humanities, and Technology 2 (4), 60–66.
Rajan, J.P., Rajan, S.E., 2018. An internet of things based physiological signal monitoring and receiving system for virtual enhanced health care network. Technology and Health Care 26 (2), 379–385.
Raimo, N., De Turi, I., Ricciardelli, A., Vitolla, F., 2021. Digitalization in the cultural industry: evidence from Italian museums. International Journal of Entrepreneurial Behavior & Research Ahead-of-print.
Raimo, N., Ricciardelli, A., Rubino, M., Vitolla, F., 2020. Factors affecting human capital disclosure in an integrated reporting perspective. Measuring Business Excellence 24 (4), 575–592.
Reis, J., Amorim, M., Melão, N., Matos, P., 2018. Digital transformation: a literature review and guidelines for future research. In: World Conference on Information Systems and Technologies. Springer, Cham, pp. 411–421.
Rippa, P., Secundo, G., 2019. Digital academic entrepreneurship: the potential of digital technologies on academic entrepreneurship. Technological Forecasting and Social Change 146, 900–911.
Saifudin, A., Aima, M., Sutawidjaya, A., Sugiyono, S., 2021. Hospital digitalization in the era of industry 4.0 based on GHRM and service quality. International Journal of Data and Network Science 5 (2), 107–114.
Sakr, S., Elgammal, A., 2016. Towards a comprehensive data analytics framework for smart healthcare services. Big Data Research 4, 44–58.
Salvi, A., Vitolla, F., Rubino, M., Giakoumelou, A., Raimo, N., 2021. Online information on digitalisation processes and its impact on firm value. Journal of Business Research 124, 437–444.
Sannino, G., De Falco, I., De Pietro, G., 2019. A continuous noninvasive arterial pressure (CNAP) approach for health 4.0 systems. IEEE Transactions on Industrial Informatics 15 (1), 498–506.
Sawyer, S., Jarrahi, M.H., 2014. Sociotechnical approaches to the study of information systems. In: Computing Handbook, third ed. Information systems and information technology. CRC Press.
Saxena, D., Raychoudhury, V., 2017. Design and verification of an NDN-based safety-critical application: a case study with smart healthcare. IEEE Transactions on Systems, Man, and Cybernetics: Systems 49 (5), 991–1005.
Scott, W.R., 1981. Organizations: Rational, Natural, and Open Systems. Prentice Hall Inc, Englewood Cliffs NJ.
Sebastian, I., Ross, J., Beath, C., Mocker, M., Moloney, K., Fonstad, N., 2017. How big old companies navigate digital transformation. MIS Quarterly Executive 16 (3), 197–213.
Secundo, G., Toma, A., Schiuma, G., Passiante, G., 2018. Knowledge transfer in open innovation: a classification framework for healthcare ecosystems. Business Process Management Journal 25 (1), 144–163.
Shepard, J.M., Hougland Jr., J.G., 1978. Contingency theory: "complex man" or "complex organization". Academy of Management Review 3 (3), 413–427.
Sjetne, I.S., Veenstra, M., Stavem, K., 2007. The effect of hospital size and teaching status on patient experiences with hospital care: a multilevel analysis. Medical Care 45 (3), 252–258.
Sørensen, J.B., Stuart, T.E., 2000. Aging, obsolescence, and organizational innovation. Administrative Science Quarterly 45 (1), 81–112.
Sousa, M.J., Pesqueira, A.M., Lemos, C., Sousa, M., Rocha, Á., 2019. Decision-making based on big data analytics for people management in healthcare organizations. Journal of Medical Systems 43 (9), 1–10.
Spanò, R., Massaro, M., Iacuzzi, S., 2021. Blockchain for Value Creation in the Healthcare Sector. Technovation, p. 102440.
Starkweather, D.B., 1970. Hospital size, complexity, and formalization. Health Services Research 5 (4), 330–341.
Tabachnick, B.G., Fidell, L.S., Ullman, J.B., 2007. Using Multivariate Statistics. Pearson, Boston, MA.
Theokary, C., Justin Ren, Z., 2011. An empirical study of the relations between hospital volume, teaching status, and service quality. Production and Operations Management 20 (3), 303–318.
Thuemmler, C., Bai, C., 2017. Health 4.0: How Virtualization and Big Data Are Revolutionizing Healthcare. Springer International Publishing, Cham.
Tortorella, G.L., Fogliatto, F.S., Espôsto, K.F., Mac Cawley Vergara, A., Vassolo, R., Tlapa Mendoza, D., Narayanamurthy, G., 2022. Measuring the effect of Healthcare 4.0 implementation on hospitals' performance. Production Planning & Control 33 (4), 386–401.
Tortorella, G.L., Fogliatto, F.S., Espôsto, K.F., Vergara, A.M.C., Vassolo, R., Mendoza, D. T., Narayanamurthy, G., 2020a. Effects of contingencies on healthcare 4.0 technologies adoption and barriers in emerging economies. Technological Forecasting and Social Change 156, 120048.
Tortorella, G.L., Fogliatto, F.S., Mac Cawley Vergara, A., Vassolo, R., Sawhney, R., 2020b. Healthcare 4.0: trends, challenges and research directions. Production Planning & Control 31 (15), 1245–1260.
Tortorella, G.L., Fogliatto, F.S., Saurin, T.A., Tonetto, L.M., McFarlane, D., 2021. Contributions of Healthcare 4.0 Digital Applications to the Resilience of Healthcare Organizations during the COVID-19 Outbreak. Technovation, p. 102379.
Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N., Haenlein, M., 2021. Digital transformation: a multidisciplinary reflection and research agenda. Journal of Business Research 122, 889–901.
Vial, G., 2019. Understanding digital transformation: a review and a research agenda. The Journal of Strategic Information Systems 28 (2), 118–144.
Visconti, R.M., Doś, A., Gurgun, A.P., 2017. Public–private partnerships for sustainable healthcare in emerging Economies. In: The Emerald Handbook of Public–Private Partnerships in Developing and Emerging Economies. Emerald Publishing Limited, Bingley, pp. 407–437.
Vitolla, F., Rubino, M., Giakoumelou, A., Petruzzella, F., Raimo, N., 2020. Signaling digitalisation through corporate websites: the effect on firm value. In: *2020* IEEE International Conference on Technology Management, Operations and Decisions, pp. 1–7.
Wang, G., Lu, R., Guan, Y.L., 2019. Achieve privacy-preserving priority classification on patient health data in remote eHealthcare system. IEEE Access 7, 33565–33576.
Wang, Y., Kung, L., Byrd, T.A., 2018. Big data analytics: understanding its capabilities and potential benefits for healthcare organizations. Technological Forecasting and Social Change 126, 3–13.
Weng, R.H., Chiu, P.S., Huang, J.A., 2006. Exploring the impact of market and organizational factors on the diversity of technological innovation of hospitals in Taiwan. Taiwan Journal of Public Health 25 (5), 372–383.
Weng, R.H., Huang, J.A., Kuo, Y.H., Huang, C.Y., Huang, Y.C., 2011. Determinants of technological innovation and its effect on hospital performance. African Journal of Business Management 5 (11), 4314–4327.
Yang, C.W., 2015. Implementing hospital innovation in Taiwan: the perspectives of institutional theory and social capital. The International Journal of Health Planning and Management 30 (4), 403–425.
Yoo, Y., Lyytinen, K.J., Boland Jr., R.J., Berente, N., 2010. *The Next Wave of Digital Innovation: Opportunities and Challenges: A Report on the Research Workshop "Digital Challenges in Innovation Research"* (Working Paper). Retrieved from. http://ssrn.com/abstract=1622170.
Yoon, S.N., Lee, D., Schniederjans, M., 2016. Effects of innovation leadership and supply chain innovation on supply chain efficiency: focusing on hospital size. Technological Forecasting and Social Change 113, 412–421.
Young, G.J., Charns, M.P., Shortell, S.M., 2001. Top manager and network effects on the adoption of innovative management practices: a study of TQM in a public hospital system. Strategic Management Journal 22 (10), 935–951.
Zhang, Y., Qiu, M., Tsai, C.W., Hassan, M.M., Alamri, A., 2017. Health-CPS: healthcare cyber-physical system assisted by cloud and big data. IEEE Systems Journal 11 (1), 88–95.