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Technology acquisition and efficiency in Dubai hospitals

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ABSTRACT

The paper studies the impact of the acquisition of relevant medical technology and information technology on the efficiency of hospital wards in three public hospitals in Dubai. Efficiency scores are obtained through bootstrapped data envelopment analysis, and are then regressed on variables assessing the extent of technology acquisition using truncated regression. Results show that both the acquisition of medical technology and of information technology have a positive impact on the ward efficiency, but that the strength of this relation is moderated by several variables related to organizational and managerial factors. In particular, results point out that the relationship between efficiency and technology is positively moderated by the ability of the head of ward to manage internal conflicts, by the managerial goals, and by the tenure of the head of ward. A negative moderating impact is exerted by perceived constraints to managerial actions, such as conflicting priorities with the hospital general management.

1. Introduction

Innovations in healthcare organizations can stem from the provision of new services, of new ways of providing care and/or from the adoption of new technologies. Technological innovation is expected to be beneficial both for the patient and for the healthcare organization, giving rise to better health outcomes, higher quality of care, and enhanced efficiency of internal operations (Länsisalmi et al., 2006). Although innovation remains fundamental in developing the quality of healthcare, reduced budgets and ensuing cost-cutting measures have pushed towards the adoption of health technologies that can improve operations by enabling efficiency and competitiveness. For instance, new medical equipment to be used in diagnosis and treatment of patients is required not only to guarantee better patient outcomes, but also to increase the productivity of hospital providers, and to reduce costs stemming from hospital errors, readmissions, and patient claims. Likewise, information technologies, while reducing the risk of hospital errors and allowing more accurate diagnoses by enabling consultations among physicians, contribute to enhance productivity by leading to significant savings of money and time (Sharma et al., 2016).

In this direction, the significant financial investment often involved in the acquisition of new technology calls for the estimation of the impact of technology on the healthcare organization performance, in order to establish what the payoffs are. There is, however, limited evidence on how the purchase of medical and information technology by hospitals is related to indicators concerning activity levels, finance, and quality, especially at the micro level (Chaudhry et al., 2006).

In addition, the adoption of technology in the healthcare sector presents other complex challenges relating to organizational, social and psychological aspects (Shortell et al., 2001), which must be carefully managed. The fact that new technology needs to be adopted and adapted to the specific organizational context and that this process of adaptation takes time, has been widely acknowledged in the literature (Devaraj and Kohli, 2003). In the same vein, new technology may require a change in the behaviours of clinicians (Venkatesh et al., 2003) or in current medical practices, requiring efforts at the group and at the individual levels (Ren et al., 2008).

While much effort has been devoted to the understanding of the technology-performance relation, of the technology adoption process (Venkatesh et al., 2003) and of the cost-quality trade-off (Gholami et al., 2015), there is still ample room for investigating the interactions between new technology, organizational and sub-organizational factors, and performance (Williams, 2011). Although capital investment in healthcare in the form of new medical equipment and IT is part of healthcare planning, its actual impact is unquestionably contingent on a set of factors, some of which operate at the sub-organizational level. For instance, in many health systems hospital units enjoy a vast discretionary power in organizing their work and in deciding appropriate treatments, and often exhibit a specific unit organizational climate (Ancarani et al., 2011). Further, even if the purchase of technology must be approved at the hospital central level, the initiation and development of the investment proposals often takes place at ward level

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within the budget allocated to the sub-organizational units. Therefore the ward's autonomy may touch on what equipment is purchased, on how the hospital unit exploits new technology, and therefore on the ward's actual performance stemming from technology acquisition (Jha et al., 2009).

This paper aims to contribute to fill this research gap by investigating how the acquisition of technology affects the production efficiency of hospital wards, and by exploring how this impact is moderated by managerial variables at the sub-organizational level and by contextual variables. Specifically, leveraging on upper echelon theory (Hambrick and Mason, 1984), we analyse how the head of ward's managerial approach in terms of managerial goals and perceived constraints, conflict management, moderate the relation between technology acquisition and efficiency at ward level. The investigation takes into account the acquisition of both relevant medical technology and information technology.

This investigation is relevant insofar as it can help uncover predictable interactions between management and technology performance, thus contributing to the management of innovation and of technology acquisition processes through evidence-based recommendations. To the best of our knowledge, this is the first paper, with the notable exception of the recent contribution by Dobrzykowski and Tarafdar (2016), that opens the black-box of the link between technology acquisition and hospital performance, looking at the sub-organizational level as unit of analysis and exploring the impact of management at that level. Finally, whereas most of the evidence on the impact of technology concerns US hospitals, this study provides evidence in a different institutional setting, namely the Dubai Health Care System, which is akin to several other healthcare systems where physicians are permanent employees of a hospital.

In order to test the hypothesis of a moderating impact of managerial factors, we proceed with a two-step analysis. First, a production frontier technique, namely data envelopment analysis (Charnes et al., 1978), is applied to estimate the relative efficiency of the wards under analysis. Next, a truncated regression analysis is adopted to investigate whether the ward's goals and constraints are related to efficiency. Our analysis considers three (out of four) public hospitals in Dubai, a country that has recently invested considerable resources and efforts in developing its healthcare system with the twofold aim to improve the health of a growing population, and to become a world hub of medical tourism. However, the actual impact of technology acquisition has not been investigated so far, while this knowledge is crucial to evaluate the opportunity of further investments, now that the flow of money has been drastically reduced by the government.

The paper is organized as follows: first, we delve on the background literature by reviewing the determinants of hospital efficiency, and the expected impact of technology acquisition, intended as both new medical equipment and IT. We then present our conceptual model and a set of testable hypotheses. A brief presentation of the organizational context under study (Dubai public Healthcare) and of the data used in the empirical analysis follows. Next, the data analysis is used to test the hypotheses formulated. The discussion and the limitation of the analysis conclude the paper.

2. Background and hypotheses development

2.1. Technology and efficiency in hospitals

Numerous scholars have called for more robust empirical evidence on the relationship between the acquisition of technology and hospital performance (Agarwal et al., 2010). In fact, although several studies have examined the impact of health and information technology on hospital performance, results are mixed (Dobrzykowski and Tarafdar, 2016). Some authors find either marginal improvements (McCullough et al., 2010) or a negative impact on hospital performance (Koppel et al., 2005; Smelcer et al., 2009), at least in the short-term (Zhivan and Diana, 2012). Kazley and Ozcan (2009), examining the relationship between hospital electronic medical record (EMR) and efficiency change over time by comparing hospitals with and without EMR, find no improvement in efficiency over time.

However, other studies report a positive impact (Devaraj and Kohli, 2003; Aron et al., 2011). In particular, examining the role of IT on patient flow and its consequences for improved hospital production efficiency and performance, Devaraj and Kohli (2003) suggest that IT is associated with improved revenues, and that this is not at the expense of quality. In another study, Menon and Kohli (2013) investigate the impact of past IT spending on the malpractice insurance premium and find that past IT expenditure is negatively associated with malpractice insurance premium and positively associated with quality of patient care. Other studies have indicated that use of new medical technology in the form of capital equipment is associated with higher service quality in healthcare (Dranove and Satterthwaite, 2000; Picone et al., 2003). In the US, Acemoglu and Finkelstein (2008) find that the increase in the capital-labour ratio and the acquisition of a range of new health care technologies brought about by the introduction of prospective payment systems has led to a significant decrease in the hospital length of stay. In turn, this reduction has led to a de facto higher hospital capacity and an increase in production efficiency. These findings suggest that health technology is not necessarily beneficial only to healthcare quality but also to operational efficiency. Based on above discussion we propose the following two hypotheses:

H1. Hospital wards benefiting from the acquisition of new health technology (medical equipment) exhibit higher levels of production efficiency.

H2. Hospital wards benefiting from the acquisition of higher levels of IT exhibit higher levels of production efficiency.

2.2. Moderating effects at the organizational and sub-organizational levels

A relevant theoretical support to our analysis can be found in the upper echelons theory (Carpenter et al., 2004; Finkelstein et al., 2009; Hambrick and Mason, 1984), which posits that the organization is a reflection of its top managers. The theory acknowledges that managers heavily influence organizational outcomes through the choices they make, which, in turn, are affected by the managers' characteristics. Hambrick and Mason (1984) further postulate that the strategic choices of the upper echelons help to explain an organization's performance. Hambrick (2007) suggests that the relationship between top management characteristics and organizational performance is strongly related to managerial discretion, referring to the latitude of action top managers enjoy in making strategic choices (Hambrick and Finkelstein, 1987; Carpenter et al., 2004). A second factor is identified by the challenges top managers face (Hambrick et al., 2005), the tougher the challenges, less time managers will have to contemplate decisions, leading them to rely more on their personal backgrounds. Thus, Hambrick (2007) predicts that the relationship between managerial characteristics and organizational outcomes will be stronger when the level of managerial challenges is high.

In hospitals, several organizational and managerial factors have been known to facilitate or conversely to hinder the beneficial effects of technology acquisition on performance (Dobrzykowski and Tarafdar, 2016). These include decision processes, organizational goals, managerial support for innovation, organizational size, relations and collaboration with other departments, staff turnover, availability of staff to implement the innovation, training and expertise (Fleuren et al., 2004). When analysing these factors it is crucial to consider the specific organizational context of hospitals, and in particular, to take into account the degree of autonomy and discretionary power enjoyed by hospital units (wards). Ward performance is largely influenced by the physicians employeed in the organization (Ilie et al., 2009), since they are the chief source of medical decision making affecting length of stay, resource utilization, and ultimately ward performance (Field et al., 2014; Fredendall et al., 2009).

Moreover, many health systems adopt the "clinical management system" (Doolin, 2001), whereby the ward manager is a physician who is entrusted not only with managing and organizing the financial and human resources of the ward but is also in charge of taking decisions that are directly perceived by patients (e.g. choosing clinical guidelines and pathways, and technologies). Accordingly, the likelihood that technology acquisition impacts on performance will crucially hinge on variables determined at the ward level, which are strongly affected by the head of ward. These characteristics include managerial goals, perceived constraints to manager's action, ability to run the unit staff by managing conflicts, experience, staff turnover. In what follows we shall elaborate on how these variables are expected to moderate the technology–efficiency relation.

2.3. The impact of hospital unit managerial goals

In many countries, the health sector is strongly characterised by the presence of public organisations, and this implies that the profit maximisation assumption has to be replaced with alternative objectives. Within hospitals there are two major actors influencing the acquisition of technology. The hospital management, whose principal goals are efficiency and quality, and the physicians, with their own goals and constraints, who are the internal customers. The consequences of this dual decision process, which makes the health sector rather unique, may be over-investment and excess capacity (Newhouse, 1970). The effects of slack investment are ambiguous: on the one hand, it may lead to inefficiency (Lee, 1971), on the other slack may also propel innovation and may increase health enhancing quality (Dranove and Satterthwaite, 2000).

A number of models have explored the way in which the goals of different actors within the hospital shapes hospital organization and input acquisition and usage. According to Newhouse (1970) and Lee (1971), not-for-profit hospitals seek to maximize the facility's quantity of services and prestige, subject to the deficit that the structure can incur. The hospital objective function reflects the interests of different agents in terms of quantity and quality. Inefficiency arises because the search for prestige may lead to duplication of sophisticated equipment and personnel. Inputs are status symbols: the more diverse, numerous and complex the inputs, the higher the hospital status. The interest of the hospital management in input availability is reinforced by the importance of the physicians to the hospital. Hospital competition for physicians boosts the expansion and improvement of inventory inputs.

When physicians are involved in the decision, they can exercise discretion in the proposal for the acquisition of medical equipment (Rodríguez-Álvarez and Knox Lovell, 2004). Physicians have their own utility in obtaining certain technological inputs, because they derive benefits in terms of personal prestige and power both inside and outside the hospital, improved working conditions, and better/new health services. If so, the acquisition of new equipment may conflict with the goal of efficiency. Wasteful purchase is further made possible by the presence of asymmetric information concerning the effective expected benefits of the technology acquisition.

If the above line of reasoning is coupled with the upper echelon theory arguments, it can be conjectured that the head of ward's goals, such as the search for status and prestige within the hospital or the competition among the wards for best performance can affect the relation between technology acquisition and efficiency. In particular, we formulate the following hypothesis:

H3. The managerial goals moderate the relation between technology acquisition and technical efficiency.

2.4. Perceived misalignment of ward management with hospital management

Harris (1977) argues that the hospital can be split into two separate firms: physicians (the demand division) and administration (the supply division). Demand and supply are disjoint, because each hospital unit may have its own objectives. Often wise, the necessity to reduce conflicts over the control of hospital capacity leads the administration to expand hospital size and capital expenditure (Cyert and March, 1963). Although in many healthcare systems heads of hospital units enjoy considerable autonomy their decisions can only take place within the framework created by the hospital general management's policy. First of all, through the process of negotiation over human resources and capital, the hospital management constraints the ward's production process. Secondly, the hospital management's policy also encompasses re-organization processes (such as mergers/splits or wards, relocation of wards to new hospital units, etc.), aimed at improving the overall performance of the hospital and which may be ill received by the single hospital unit involved.

A misalignment between priorities of the hospital management and of wards is bound to have negative effects on performance. Venkatraman and Camillus (1984) conceptualized the need for "strategic alignment" of priorities throughout the organization and claimed that strategic consensus is achieved when various levels of employees within an organization agree on what is most important for the organization to succeed. Recently Dobrzykowski and Tarafdar (2016) have empirically verified that EMR use should be complemented by processual, social, and structural mechanisms to yield positive effects on performance.

Hospital management and wards' management find it increasingly difficult to function efficiently as separate entities and need alignment of their goals to create safe and high-quality care at lower cost (Sonnenberg, 2015). We conjecture that the misalignment has an impact not only on the amount of technology made available to the wards, but also on the effectiveness of the technology, above all when information technology investments are involved (Tarafdar and Qrunfleh, 2010).

H4. A perceived misalignment between the goals of the hospital general management and those of the hospital unit negatively moderates the relation between technology acquisition and technical efficiency.

Upper echelon theory implies that the number of years of inside service by a manager are negatively related to the adoption of strategic changes. Previous research has indicated that managers tend to become more conservative toward changes as their tenure increases (Musteen et al., 2006). This is because as the years of tenure increase, the manager becomes more committed to implementing their own paradigms (Hambrick and Fukutomi, 1991). For instance, longer-tenured managers may refrain from making changes and investments required to make the IT strategy innovative and flexible over time (Miller, 1991). Elaborating on Hambrick and Mason (1984) we conjecture that when heads of wards have longer tenures within the hospital, the relation between technology acquisition and efficiency will be negative, because they will exhibit more conservative attitudes towards new technology. This hypothesis may be corroborated by the fact that long-tenure may be a proxy for age, which has been proven to have a negative impact on attitude to use technology (Morris and Venkatesh, 2000).

H5. Longer organizational tenure of the head of hospital ward negatively moderates the relation between technology acquisition and technical efficiency.

2.5. Task Conflict Management

The operations of high-reliability organizations such as hospitals encompass complex and dynamic activities that exhibit a high degree of interdependence and are often non-routinary. Undeniably, the success of hospital care relies on the collaboration among multiple groups

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of professionals. This collaboration builds on effective communication and coordination among different groups of providers whose tasks are tightly coupled and highly interdependent on each other (Ren et al., 2008). The presence of task conflicts inside a hospital unit will impede effective coordination and collaboration, having an adverse effect on performance (De Dreu and Weingart, 2003). By the same token, the successful adoption of new technology, e.g. IT and hospital digitalization, will critically hinge on a process of coordination and collaboration among care givers and administrative staff. Failure to agree on "who does what" will lead to weak implementation and weak performance benefits. Further, most hospital information systems meet specialized needs (e.g. scheduling, waiting list management, billing, pharmacy, warehouse). Since these systems often exhibit very limited integration ex ante (Kim and Michelman, 1990), their effective integration requires cooperation and is therefore at odds with the presence of task conflicts. Therefore, when the ward manager is effective at managing task conflicts the integration of information and cooperation is smooth, leading to higher efficiency (Shortell et al., 1994).

H6. Task conflict management positively moderates the relation between technology acquisition and technical efficiency.

2.6. Learning and adaptation: the moderating effect of staff turnover

The positive effects of technology (especially for IT) have been unequivocal and positively correlated to its usage (Trice and Treacy, 1988). In particular, several scholars have identified usage as the main discriminator on the impact of IT on performance (Devaraj and Kohli, 2003). People are often unwilling to change and to use IT, even if it could improve their job performance, because they do not have sufficient knowledge of the technology or do not receive adequate support from their work environment or the organization.

Venkatesh et al. (2003) find that experience is a significant moderator of the relation between expected performance and actual usage. Therefore, elaborating on this concept, one might argue that when turnover is high, this will decrease technology usage and performance in terms of efficiency. The health care industry is in fact primarily composed of professionals and is characterized by high knowledge requirements, demanding high levels of training. Turnover will negatively affect the linkage between technology acquisition and efficiency because it leads to the loss of valuable knowledge of the technology and skills employees have developed through experience and training (Hancock et al., 2013).

H7. Staff turnover negatively moderates the relation between technology acquisition and technical efficiency.

Fig. 1 summarises the hypothesised model. The following sections present a test of the hypotheses developed in this section, based on data collected in Dubai. In the application, the relative efficiency of the wards under analysis is measured through a production frontier technique (Data Envelopment Analysis). Next, efficiency scores are regressed on a measure of technology purchase and moderation effects at hospital unit level are analysed.

3. The Dubai National Health Service

The United Arab Emirates (UAE) federal Government is made up of seven emirates. The sharp increase and wide distribution of the population in the UAE following the vast socio-economic development in the last three decades made it imperative for the Ministry of Health to seek a decentralized strategy for providing health services. Since 2001, the public healthcare sector has been administered through three main zones: a southern zone encompassing the emirate of Abu Dhabi, a central zone located in the emirate of Dubai, and the northern zone including the northern emirates. In the central zone of the Emirate, which concern primarily our analysis, the Dubai Health Authority (DHA) is in charge of both local regulations and service provision (Ayach, 2013). Currently DHA is responsible for 4 main hospitals and over 29 primary health care and health centres. DHA was created with the aim to create a world-class integrated health system that ensures excellence in healthcare for the Emirate of Dubai and promotes Dubai as a globally recognized destination for medical care (Ayach, 2013).

In the past years, the government has undertaken extensive investment in the development of health services: key projects under the new strategy include rebuilding and regenerating existing hospitals as well construction of new hospitals and primary health care centres. In the emirate of Dubai, in particular, the government has endeavoured to create a new provider system based on best practices from around the world. In fact, the Dubai Strategic Plan for 2020 has aimed to develop world class health services for Dubai residents and the thriving medical tourism market targeted at patients looking for high quality but low cost treatments in internationally accredited hospitals (Ayach, 2013).

Concerning the effects that the investment plan may bring on the acquisition of capital inputs by hospitals, the expected impact is ambiguous. On the one hand, competition among providers and among hospitals may lead to the so-called "medical arms race", i.e. rising costs, duplication of services, and under-utilization of equipment. The competition to become a global health service provider where competition is not acted on the basis of price, but rather on the basis of hospital status (Lee, 1971), or hospital location (Kessler and McClennan, 2000) might affect the approach to technology purchasing. Assuming quality of care is a multi-attribute concept (Chalkley and Malcomson, 2000), medical equipment may be one of the attributes most easily observable by patients. Thus, the hospital management may encourage the purchase of new and sophisticated equipment in order to increase its market share, and as a result, it is not unlikely that excess capacity is observed in equilibrium (Joskow, 1980).

4. Methodology

4.1. Data

We estimated the efficiency of the hospital wards by modelling a production function with three inputs and three outputs. In accordance with the literature on hospital efficiency measurement (Blank and Valdmanis, 2010; De Nicola et al., 2013; Hollingsworth and Peacock, 2008), the inputs are number of beds, number of doctors and number of nurses, while the outputs are inpatient surgery discharges, inpatient

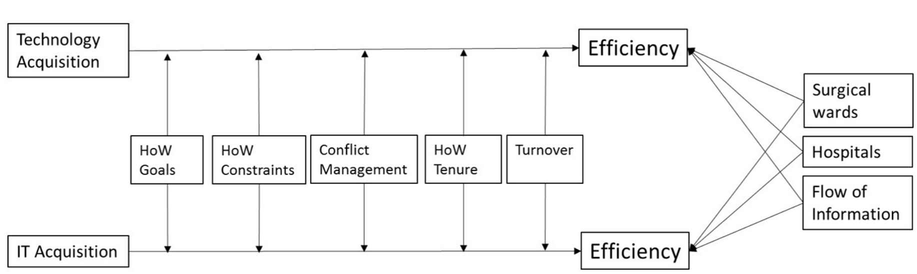

Fig. 1. Moderation effects of the relation between technology acquisition and production efficiency.

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non-surgery discharges and outpatients. Data referring to end of 2012 were obtained from the Dubai Health Authority (DHA). We analysed three (Latifa, Dubai, Rashid) out of four public hospitals in Dubai: one hospital has been excluded from the analysis because it has been established recently. The three hospitals are comparable in terms of size, organization and provision of healthcare services. In fact, there are 48 wards in each hospital and slight differences in the number of beds: 629, 590 and 484 for Dubai, Rashid and Latifa respectively. There are no differences among these three hospitals in terms of funding, teaching status and public status.

Forty-four wards were excluded from the analysis because their output levels were extremely low. The wards of Radiology, Intensive Care, Emergency Care and Neonatology Intensive Care were excluded because their high intensity of resource absorption would have biased efficiency estimates (Ancarani et al., 2009). The heads of the remaining 73 wards were asked to complete a questionnaire in January 2013. The questionnaire encompassed four sections. The first section, consisted of general questions concerning the head of ward. The second section contained questions relating the adoption of key information technology and the acquisition of new and relevant medical equipment in the period analysed. The third section of the questionnaire addressed the managerial goals and constraints of the head of the hospital ward and information on other managerial issues. Sixty-six completed questionnaire were returned with a response rate of 90%. Table 1 reports the main descriptive statistics of the input-output variables and their correlations for the wards included in the sample. The high correlations among variables make possible to use a methodology for reducing the number of inputs and outputs as discussed in the next section.

Table 2 describes the variables obtained from the questionnaire and used in the second stage of the analysis to explain the technical efficiency of the wards, whereas Table 3 reports descriptive statistics. In order to keep the specificities of medical equipment and of IT into account, the acquisition of technology was separated into two dependent variables, namely equipment (for diagnosis or treatment) and IT. In both cases, the heads of wards were asked to assess the extent of new acquisition on a four point Likert scale (0–3), where zero indicates no acquisition. Control variables were meant to capture contextual variable that may affect efficiency, other than technology acquisition and moderators. The overall hospital context was kept into account through the use of two hospital dummies (*D hospital* and *R hospital*), which signalled whether efficiency dependent on the specific hospital under analysis (D for wards in Dubai hospital and R for wards in Rashid hospital). On average, surgical wards tend to be more complex than medical wards and entail a higher resource absorption, since surgery more often requires specialised facilities (Becker and Steinwald, 1981) and exhibits a higher degree of interdependence among tasks. In order to keep this heterogeneity between medical and surgical wards into account, a dummy for surgical wards (*Surgical*) was included in the second stage model. Finally, the perceived efficacy of information inside the ward was also used to predict the level of efficiency (*Flow of information*).

As for moderators, three possible managerial goals of the head of ward were initially considered: maximize number of admissions (*Max admissions*), maximise revenue from ward activity (*Max revenue*), maximise the ward's prestige and status (*Max prestige*). However, since the last two were never statistically significant, they were removed form model estimation to make the model more parsimonious. The perceived alignment between the ward and the general management of the hospital was measured by the level of perceived constraint represented by the priorities of the hospital general management with respect to those of the head of ward (*Alignment of priorities*). Tenure of the head of ward (*Tenure*) was measured by the number of years since the designation of the head of specialty. To measure task conflict management inside the ward (*Conflict*), three types of task conflicts were considered: among nurses, among physicians, and across medical roles. Each head of specialty declared whether he/she had successfully managed conflicts of the kind indicated. Then, an aggregate score was built, taking value 0 if all types of task conflict had been successfully managed, and value 1/2/3 if one/two/three types of conflicts were present. Therefore, the score measures the manager's perceived failure to manage task conflicts. The variable

Table 2
Explanatory variable definition.

Variables	Definition
KEY INDEPENDENT VARIABLES	
Acquisition of IT	Score from 0 to 3 according the extent of acquisition of key information technology as declared by the head of ward.
Acquisition of medical technology	Score from 0 to 3 according to the extent of acquisition of relevant medical technology (equipment) as declared by the head of ward.
CONTROL VARIABLES	
D hospital	Dummy for the wards in Dubai hospital
R hospital	Dummy for the wards in Rashid hospital
Surgical	Dummy for surgical specialties
Flow of information	Score from 1 to 5 according to the evaluation on the efficacy of communication and flow of information inside the ward.
MODERATING VARIABLES	
Max admissions	Score from 1 to 5 according to the importance given by head of ward to the maximization of the number of cases treated by the ward
Max revenues	Score from 1 to 5 according to the importance given by head of ward to the maximization of the revenues deriving from the ward's activity
Max prestige	Score from 1 to 5 according to the importance given by head of ward to the maximization of ward's prestige and status within the hospital
Misalignment of priorities	Score from 1 to 5 according the level of perceived constraint represented by the misalignment with priorities of the hospital general management
Tenure	Tenure of the head of ward measured in years
Conflict	Score from 0 to 3 according to the perception by the head of ward of the presence of unmanaged conflicts among staff
Turnover	Categorical variable according to the percentage of staff turnover (1 = less than 15%, 2 = between 16 and 30%, 3 = between 31 and 50%, 4 = over 50%

Table 1
Descriptive statistics and correlations.

Variable	statistics				correlations					
Inputs	Mean	SD	Min	Max	1	2	3	4	5	6
1. Number of physicians	10.33	8.14	1.00	38.00	1.00					
2. Number of beds	19.74	22.80	1.00	126.00	0.71	1.00				
3. Number of nurses	32.38	31.40	4.00	123.00	0.89	0.63	1.00			
Outputs										
4. Number of outpatients	6324.00	8297.62	6.00	50,600.00	0.16	0.14	0.07	1.00		
5. Number of inpatient surgery	281.90	582.29	0.00	3232.00	0.68	0.66	0.66	0.10	1.00	
6. Number of inpatient non-surgery	802.90	1363.35	0.00	7806.00	0.41	0.49	0.31	0.16	0.15	1.00

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Table 3
Descriptive statistics and correlations of the second stage variables.

		statistics				correlations									
		Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10
1	D hospital	0.348	0.480	0	1	1.000									
2	R hospital	0.318	0.469	0	1	−0.500	1.000								
3	Surgical	0.257	0.440	0	1	−0.067	−0.105	1.000							
4	Tenure	6.030	3.314	1	15	−0.132	0.023	0.121	1.000						
5	Turnover	1.818	0.762	1	4	0.134	−0.008	0.233	0.069	1.000					
6	Conflict	0.833	0.833	0	3	0.032	−0.138	0.202	0.108	0.024	1.000				
7	Misalignment of priorities	5.273	0.985	3	7	0.154	−0.324	0.084	0.073	0.128	0.150	1.000			
8	Flow of information	2.348	0.774	1	4	0.082	0.198	0.003	0.302	0.031	0.115	−0.147	1.000		
9	Max admissions	1.879	0.850	1	4	−0.422	0.291	−0.121	−0.113	−0.177	−0.181	−0.254	0.088	1.000	
10	Acquisition of IT	1.894	0.725	1	3	−0.157	−0.035	0.087	0.315	0.131	−0.004	−0.023	0.231	−0.046	1.000
11	Acquisition of medical technology	1.000	1.123	0	3	−0.285	−0.058	0.280	0.021	−0.162	0.246	0.014	0.265	−0.048	0.340

turnover measures the estimated percentage of annual staff turnover (*Turnover*) and is it taken to reflect HRM practises inside the ward.

4.2. Two stage approach

A two-stage approach was adopted to investigate the impact of a set of contextual variables on the technical efficiency of the wards of three out of the four public hospitals in Dubai. In the two-stage Data Envelopment Analysis (DEA) method, in the first stage the efficient frontier and the efficiency scores are estimated with DEA (Wu and Guo, 2015; Chen and Chen, 2011), while the estimated efficiency scores are regressed on some contextual variables in the second stage. Simar and Wilson (2007) discussed the data generating process and the serial correlation that affect two-stage DEA estimates, arguing that the conventional methods of statistical inference are invalid. The authors propose the use of bootstrap methods to correct for the bias and serial correlation of the DEA efficiency estimates. Furthermore, they advocate the use of the truncated regression model that takes into account explicitly the bounded domain of the DEA efficiency estimates. In this paper we follow their methodology, in line with a growing literature on the determinants of efficiency in the health care industry (Blank and Valdmanis, 2010; De Nicola et al., 2013, 2014; Hollingsworth and Peacock, 2008).

4.2.1. First stage: DEA

DEA was developed by Charnes et al. (1978) and it is a non-parametric method to determine the efficiency scores of a set of units (Wu and Guo, 2015; Chen and Chen, 2011). In production theory, efficiency scores refer to the distance of a production unit from the best practice, which constitutes the frontier. In such model, the technology defines the production frontier and the relationship between inputs and outputs. In mathematical terms, given the assumption of variable returns to scale and output orientation, the efficiency scores are obtained by providing the solution to the following linear problem:

$$\begin{aligned} \hat{\theta}_i = {} & \max_{\theta\lambda}\theta \\ s.t. \quad & x_i \le X\lambda \\ & \theta y_i \le Y\lambda \qquad i = 1, 2\ldots\ldots, n; \\ & 1'\lambda = 1 \\ & \lambda \ge 0 \end{aligned} \tag{1}$$

Where $\hat{\theta}_i \ge 1$ is a measure of the technical efficiency, n is the number of wards, Y is a sxn matrix of s outputs, X is a rxn matrix of r inputs, λ represents a nx1 vector of weights which allows obtaining a convex combination between inputs and outputs and $1'$ is a vector of ones. $\hat{\theta}$ is an inefficiency measure and always assumes a value equal to or greater than one. Units with efficiency scores equal to one are located on the best practice frontier, meaning their outputs cannot be expanded further without a corresponding increase in inputs. The model (1) does not require assumptions about the functional form of the production frontier (Daraio and Simar, 2007) but it is based on an estimate of the true (and unknown) production frontier, conditional on observed data resulting from an underlying data generating process (Simar and Wilson, 2008). Hence, the DEA estimator is biased by construction and suffers from the curse of dimensionality, which depends on the numbers of inputs and outputs used. To overcome this issue, it is possible to use a consistent bootstrap estimation procedure to approximate the sampling distributions of the technical efficiencies by simulating their data generation process. Then Bias-corrected efficiency scores are obtained from the bootstrap sample (Simar and Wilson, 1998, 2008).

We assume an output specification model following the related literature (De Nicola et al., 2013; Ancarani et al., 2009). This approach implies that managers can attract patients trough marketing and/or by increasing reputation on services quality. In this paper, the output orientation was chosen, since the aim is to identify potential sources of efficiency improvement in order to increase the demand for services provided by the Dubai health system.

Due to lack of data on each specialty's case mix, it was not possible to keep this source of heterogeneity in specialties' input-output mix into account. In order to reduce cross-ward heterogeneity, two groups of wards are analysed separately: medical and surgical. Further, following O'Donnell et al. (2008), we use the concept of metafrontier. The group frontiers are defined as the boundaries of the restricted technological sets, while the metafrontier is the boundary of an unrestricted technology set and it is the envelopment of the group frontiers. Thus, three efficiency measures are obtained for each ward: a measure relative to the metafrontier $\hat{\theta}_i^{MF}$ (the distance of the ward from the metafrontier), a measure of the distance to the group frontier $\hat{\theta}_i^{GF}$ (which is our measure of technical efficiency) and a resulting component that measures the distance between the group frontier and the metafrontier (meta-technology ratio).

The group frontiers are estimated by the linear program (1) for each group. The estimation of the metafrontier is obtained by applying the same DEA model (1) to the data set obtained by considering both groups. Then the meta-technology ratio is obtained as $MTR_i = \hat{\theta}_i^{MF} / \hat{\theta}_i^{GF}$.

Further, because our sample is made up of a small number of units, relative to the number of inputs and outputs, the DEA model loses discriminative power. This is called "curse of dimensionality" and can be reduced by employing the technique proposed by Daraio and Simar (2007). Whenever the correlation among inputs (outputs) is high (see Table 1), it is possible to reduce the number of variables to one input and one output, with minimal loss of information. Hence, we aggregated the three inputs and three outputs described below into one input factor and one output factor. Mathematically, the factor A-, is obtained as follows: A = Xa, where X is the matrix of the input (output) variables and a is the first eigenvector of the matrix XX' (Daraio and Simar, 2007).

4.2.2. Second stage: truncated regression

In the second stage, we test the hypothesis discussed above, using a truncated regression to examine the effects of a set of explanatory variables on wards' technical efficiency:

$$\hat{\theta}_i = z_i\beta + \varepsilon_i \qquad i = 1, 2, \ldots\ldots, n; \tag{2}$$

Where $\hat{\theta}_i$are the efficiencies, z_i is a set of explanatory variables and $\varepsilon_i$is N(0,σ) with left-truncation at $1 - z_i\beta$. Since xi and yi are correlated with zi, the error term ε_i in (2) is correlated with z_i, thus violating the basic regression assumption. This problem was solved by estimating the truncated regression with a double bootstrap method Simar and Wilson (2007).

5. Results

Table 4 shows the geometric means at hospital level of the bias corrected efficiency scores for medical and surgical wards. Values closer to 1 indicate higher efficiency.

The second column of the table reports the group frontiers while the third column represents the metafrontier. The last column of the table indicates the technology gap ratio. Regarding results of the group frontiers, it is interesting to note that the wards that provide more intensive care, namely the surgical wards, exhibit a considerably higher level of production than that achieved by the medical ones. This means that, on average, the surgical wards operate closer to their own frontier than medical wards.

Considering the technical efficiency of the metafrontier, we observe that the surgical wards are the less efficient with respect to the metafrontier and, as a consequence, the MTR ratio is higher in such wards, indicating that the own frontier is far from metafrontier. Furthermore, the differences of MTR ratio between the surgical and medical wards, confirm our estimate strategy: in fact, there are differences in MTR scores only when the groups determine different frontiers, because they use different technologies. In what follows, the two stage results are based on efficiency scores relating to the group frontier, in order to take into account the different technologies.

In order to test the moderation hypotheses discussed above, we built several truncated regression models, using the efficiency score of the ward as the dependent variable. We estimate the impact of the technology acquisition on efficiency using two different models (one considering the impact of IT and the other of medical technology as equipment). For each model, two different specifications are estimated: the M0 specification considers only the main effects, while model M1 includes also linear interaction terms, in order to test for moderating effects (Aiken and West, 1991; Dawson, 2014). All non-dummy variables are standardized. The results are reported in Tables 5 and 6. The dependent variable is an inverse measure of efficiency; therefore, negative coefficients in Tables 5 and 6 indicate efficiency improvement and positive coefficients indicate efficiency decline.

Table 5 reports the estimated coefficients for the specifications related to the acquisition of relevant medical technology (equipment). In both models, medical technology is positively related to ward efficiency, consistent with H1. Various control variables are significantly related to ward efficiency. Specifically, there are significant effects tied to the hospital (Dubai hospital) and to surgical activities, which are associated with a higher level of performance. The efficacy of the flow of information is not related to the ward's efficiency. In Model M1, all the interaction terms are significant, thus supporting the hypotheses that the head of ward's goals, the alignment with the hospital's priorities, the tenure of the head of ward, task conflict management, and staff turnover moderate the impact of acquisition of medical technology on efficiency.

Table 6 reports the estimated coefficients for the specifications relating to the acquisition of IT. The acquisition of IT is positively related to ward efficiency in model M0 but not in M1, thus lending partial support to Hypothesis H2. The variable related to communication and flow of information is significant and suggests a positive impact on efficiency. Surgical wards exhibit a significantly higher efficiency than medical wards. Contextual variables capturing hospital level characteristics are not statistically significant. Turning to moderating effects, in M1 only three interaction terms are significant. Specifically, the alignment of

Table 4
Geometric mean of the bias corrected efficiency scores by hospital.

Medical wards	Group frontiers	Metafrontier	MTR
Rashid hospital	4.404	4.516	1.025
Dubai hospital	2.825	2.896	1.025
Latifa hospital	3.940	4.163	1.057
Surgical wards			
Rashid hospital	1.904	2.868	1.506
Dubai hospital	2.299	3.456	1.504
Latifa hospital	1.814	2.501	1.378

Table 5
Second stage results - Acquisition of medical technology.

Variable	M0	M1
Intercept	2.353	−1.246**
D hospital	−6.814***	−6.305**
R hospital	−2.832**	0.322
Surgical	−7.461***	−5.892**
Flow of information	0.736	0.562
Acquisition of medical technology	−4.811***	−8.104***
Max admissions	0.109	2.065***
Misalignment of priorities	−1.242**	3.898***
Tenure	−2.088***	−0.252
Conflict	2.129***	2.524***
Turnover	−0.410	−2.227***
Interactions		
Acquisition of medical technology * Max admissions		2.550***
Acquisition of medical technology * Alignment of priorities		3.871***
Acquisition of medical technology * Tenure		2.454***
Acquisition of medical technology * Conflict		−2.457**
Acquisition of medical technology * Turnover		1.798***
Sigma	4.358***	3.954***

Statistical significance: *** (1%), ** (5%), * (10%), according to bootstrap confidence intervals. Dependent variable: DEA-VRS estimates ≥1.

Table 6
Second stage results - Acquisition of IT.

Variable	M0	M1
Intercept	−3.784**	−0.562*
D hospital	−2.203	0.178
R hospital	2.056	0.406
Surgical	−15.118***	−7.170***
Flow of information	−2.083***	−1.439***
Acquisition of IT	−1.349**	−0.600
Max admissions	2.399***	0.997**
Misalignment of priorities	1.847***	1.617***
Tenure	−1.256*	−1.758***
Conflict	1.918***	0.176
Turnover	0.412	0.090
Interactions		
Acquisition of IT * Max admissions		−0.673
Acquisition of IT * Alignment of priorities		1.694***
Acquisition of IT * Tenure		2.285***
Acquisition of IT * Conflict		−0.521
Acquisition of IT * Turnover		1.610***
Sigma	5.806***	3.614***

Statistical significance: *** (1%), ** (5%), * (10%), according to bootstrap confidence intervals. Dependent variable: DEA-VRS estimates ≥1.

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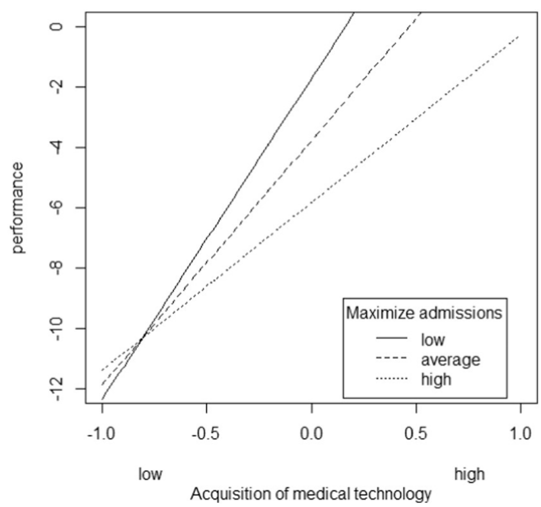

Fig. 2. A. Interaction effect of acquisition of medical technology and the goal to maximize number of admissions.

the ward management with the hospital general management, the tenure of the head of ward and staff turnover moderate the impact of of IT on ward efficiency. By contrast, there is no evidence of a moderating role played by conflict management and by managerial goals, since the respective interaction terms are not statistically significant.

6. Discussion of moderation effects

In order to test whether the moderating variables support hypotheses H3-H7 developed in Section 2, following Aiken and West (1991); Dawson (2014); Srivastava et al. (2015), and Amores-Salvadó et al. (2015), we performed a graphical slope analysis (Figs. 2–6). On the horizontal axis we plot low/high levels of acquisition of technology, while the vertical axis represents the corresponding measure of performance. This measure of performance was obtained by inverting the inefficiency measure obtained from the first stage of the analysis. Low/High technology acquisition indicates values of acquisition ± one standard error from the mean, whereas zero indicates the mean value. The slope analysis was undertaken only where the interaction term was statistically significant. The different curves for each figure capture the impact of specific values (low, average, high) of the moderating variable under analysis.

Figures labelled "A" refer to medical technology acquisition, whereas figures "B″ refer to IT acquisition. With reference to the acquisition of medical technology, the positive slope of the relations in "A" figures shows that the impact of the acquisition of medical technology on ward performance is always positive, irrespective of the value of the moderating variable. Conversely, for "B″ figures, high alignment with hospital priorities, high tenure and high turnover determine a switch from positive negative in the relation between IT acquisition and performance. These results are discussed in detail in what follows.

Results support hypothesis H3 concerning the relevance of managerial goals as far as medical technology is concerned, given that the interaction term with IT is not statistically significant. Fig. 2A summarizes the interaction effect of the goal to maximize the number of admissions on the relationship between medical technology acquisition and ward performance. Contrary to intuition, the importance attached to this goal reduces the slope of the impact of medical technology on performance. This counterintuitive result may be explained either by a reverse causation effect, whereby less efficient hospital wards feel that they ought to prioritize the number of cases treated, or by the fact that the goal to maximise admissions may interfere with the correct scheduling of patients, leading to an incorrect planning of the workload and reducing production efficiency (Adan and Vissers, 2002).

Fig. 3a shows that a misalignment of the ward priorities with hospital general management negatively affects the relationship between adoption of relevant medical technology and ward performance. As the misalignment increases, the relation between technology and performance becomes flatter. This result confirms hypothesis H4 and implies that when new technology is introduced in the hospital, care should be put in ensuring that all units fully perceive the relevance of the new technology.

The effect of the misalignment is even more dramatic when the relation between IT acquisition and performance is analysed (Fig. 3B). In fact, there is a positive relationship between acquisition of IT and ward performance if the misalignment is low or moderate but this relation becomes negative if the misalignment is high.

This confirms that organizational support is important for IT actual success in hospitals (Bhattacherjee and Hikmet, 2008), and suggests that one of the pathways through which this may be achieved is the effort to align managers in charge of hospital operations (the heads of ward) and hospital administration along the same priorities.

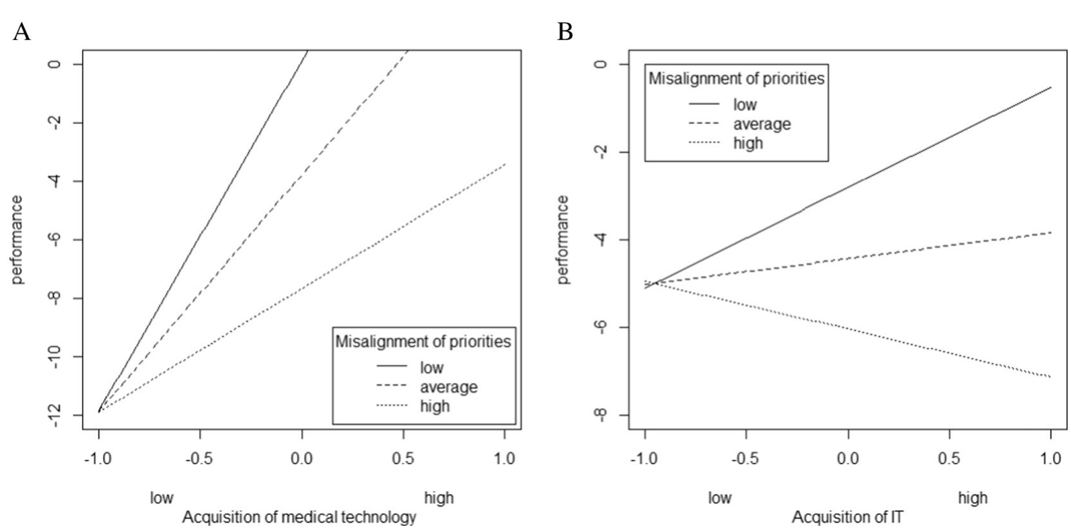

Fig. 3. A. Interaction effect of acquisition of medical technology and misalignment of priorities between ward and hospital general management. B. Interaction effect of acquisition of IT and misalignment of priorities between ward and hospital general management.

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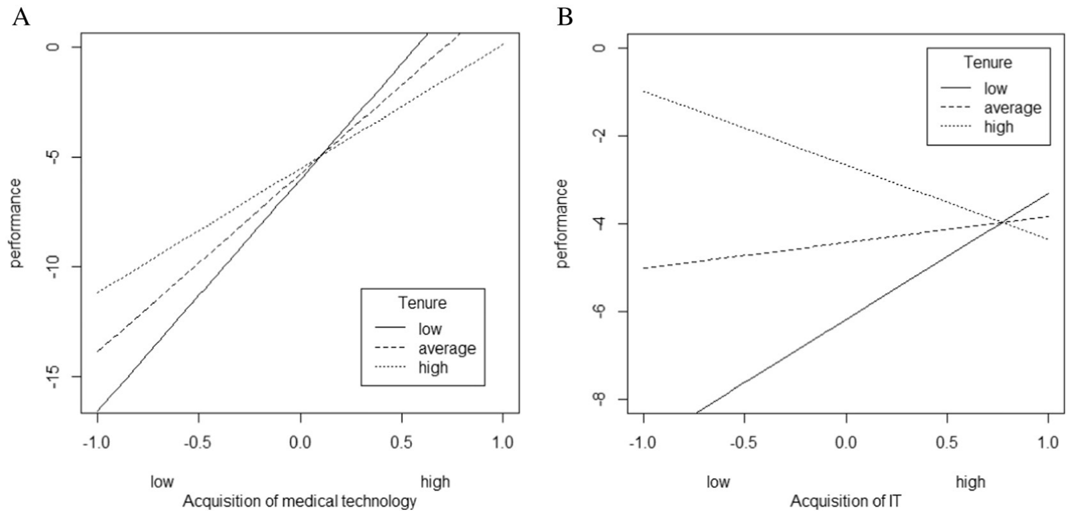

Fig. 4. A. Interaction effect of acquisition of medical technology and tenure of the head of ward. B. Interaction effect of acquisition of IT and tenure of the head of ward.

Consistent with hypothesis H5, the moderating effect of the tenure of the head of ward is significant both for medical equipment (Fig. 4A) and for IT (Fig. 4B). In particular, consistent with H5 and previous literature, low tenure is beneficial to the relation between medical equipment and efficiency when technology acquisition is high. Instead, for low levels of acquisition of medical technology, wards with a longer tenure have a better performance. These results suggest that tenure of the proximity manager (the head of ward) is useful in a number of ways (for instance, it may be effective in achieving a better organization of workloads). However, longer tenured (and maybe older) managers may not have the necessary enthusiasm to support effective usage of new technologies.

The negative effect of tenure emerges unambiguously also in the case of the acquisition of IT: Fig. 4B shows that there is a positive relationship between IT and ward performance if tenure of the head of ward is low but this relation is negative if the moderator is high. Therefore, as more tenured managers are called to guide the implementation and implementation of IT investments, the efficiency of the ward will decrease, probably because of lack of understanding of the new information technology by the manager and to the inability to guide the transition process to new automated data processes (e.g. EHR) (Burke et al., 2002).

The moderating effect of task conflict management within the ward provides evidence in support of Hypothesis 6. Wards with high adoption of medical technology exhibit a better efficiency performance if conflict is low with respect to the case in which conflict is high (Fig. 5A). This finding confirms H6 and strengthens the case for a high level of coordination and cooperation within hospitals in order to make adoption and usage of new technology effective and beneficial to performance. As it will be recalled from the results section, conflict management is not a significant moderator in the case of IT acquisition.

Contrary to hypothesis H7, the moderating effect of staff turnover is significant but positive both for medical technology and IT. Wards with high turnover and high adoption of medical technology are more efficient than wards with low staff turnover (Fig. 6A).

This difference is null for low adoption of medical technology, suggesting that high turnover is beneficial only when an extensive effort is undertaken to introduce new technology inside the ward. This seemingly counterintuitive result may be explained by the fact that staff stepping down from their position or being laid off may be those who exhibit greater resistance to changes.

The analysis of the moderation effect of staff turnover when IT is considered (Fig. 6B) shows that there is a positive relationship between IT and ward performance if turnover is low or average. However, this relation is negative if the moderator is high. Therefore, unlike for new medical equipment, turnover is detrimental when the ward engages in an extensive effort to digitalize its processes. We conjecture that this finding may be attributed to the fact that EHR or administrative databases are often created ad hoc to tailor the requirements of the specific hospital. Therefore, high turnover implies that training on the use of the specific digital technologies must be provided to all new staff, thus lowering the ward's efficiency.

7. Conclusions

This paper has investigated the impact of the acquisition of new medical technology and of IT on the efficiency of hospital wards, and has analysed the impact of moderators of this relation that stem from the management of the hospital ward and from its relation with the hospital general management.

Notable results of our analysis for managerial practice are that the misalignment between wards' and hospital management priorities is detrimental to the relation between technology adoption and efficiency. This result calls for a close alignment between the technology purchased by the hospital and wards' technological needs, e.g. through a shared decision process among physicians and hospital administrators when technology adoption is at issue.

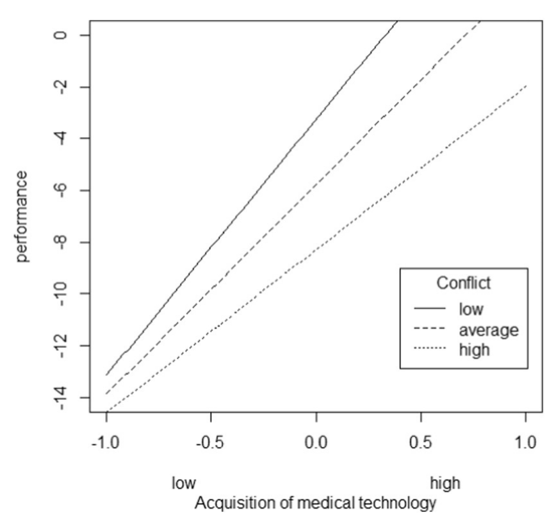

Fig. 5. A. Interaction effect of medical technology and conflict.

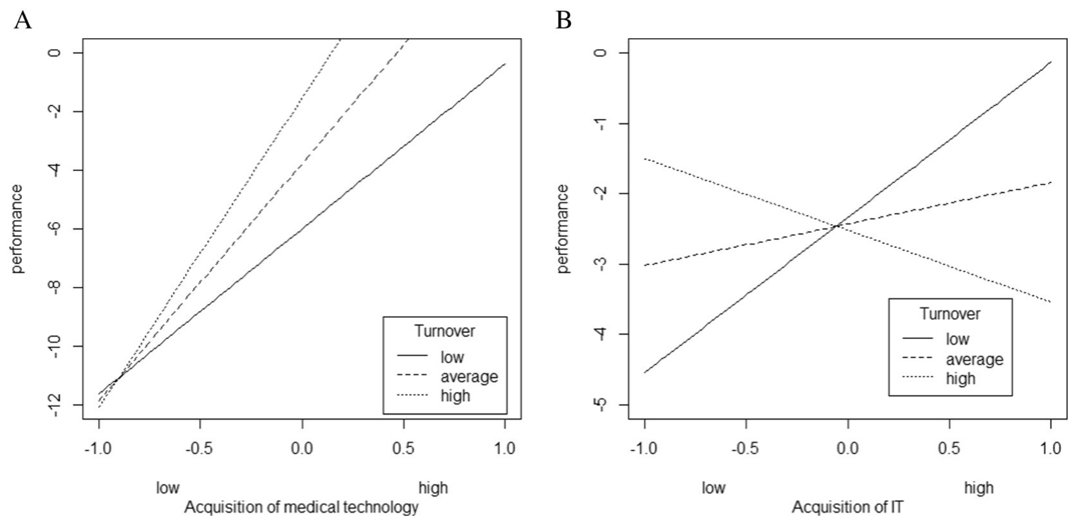

Fig. 6. A. Interaction effect of medical technology and staff turnover B. Interaction effect of IT acquisition and staff turnover.

Another notable result concerns the negative role that task conflict exerts on the relation between acquisition of technology and production efficiency. This result gives the ward manager a crucial role in facilitating technology usage and implementation through conflict management and the creation of a collaborative climate inside the ward.

Our model also shows a significant role of the organizational tenure of the head of ward as an element impeding the beneficial effects of technology (both medical equipment and IT) on ward performance. Plausibly, shorter tenure is associated with younger and more dynamic heads of ward, who have a fresh enthusiasm for new technologies and digitalization. On the other hand, the effect of high staff turnover is controversial, as it is beneficial when new equipment is analysed but is detrimental for IT, an effect we have explained by the organization-specific nature of some information technology.

While the above findings may plausibly apply to all hospital organizations irrespective of their size, specialization and location in the world, we think that specific recommendations can be drawn for Dubai healthcare. In the last decade, Dubai has undertaken an ambitious plan to build a world class health system. The sustainability of this new health system requires that that investments are paid off not only through an increase in quality but also by an increase in demand and efficiency of care provision. Our analysis suggests that new managers at the head of hospital wards may play an important role in facilitating technology adoption and in supporting the implementation of the healthcare strategic plan. At the same time, the importance of managerial actions at ward level suggests the need to carefully design also hospitals' organizational systems and incentives, in order to devise organizations that facilitate shared decision making on crucial issues such as technology acquisition and adoption. Future research will be called to assess the degree to which these goals are achieved by Dubai healthcare system. In particular, it would be of particular interest for future research to verify whether the strategic goal to attract foreign medical tourism will lead to wasteful acquisition of technology, as suggested by some models of hospital behavior, or will instead foster performance along different dimensions.

To conclude, some limitations of the present study must be acknowledged. First, the study relies on perceptual measures of technology acquisition. Next, since information on hospital case mix is not collected in Dubai hospitals, it was not possible to control for this source of heterogeneity among hospital wards. Finally, the analysis would benefit from an explicit comparison of strategies decided at hospital level and managerial decisions at ward level in order to uncover specific sources of misalignment.

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