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Full Length Research Paper

Determinants of technological innovation and its effect on hospital performance

Rhay-Hung Weng[1], Jin-An Huang[2,3]*, Yen-Hung Kuo[1,4], Ching-Yuan Huang[5], and Yu-Chi Huang[1]

[1]Department of Hospital and Health Care Administration, Chia Nan University of Pharmacy and Science, No. 60, Section 1, Erh-Jen Rd., Jen-Te, Tainan, 717, Taiwan, R.O.C.
[2]Department of Emergency Medicine, Taichung Veterans General Hospital, No. 160, Sec. 3, Chung-Kang Rd., Taichung, 407, Taiwan, R.O.C.
[3]Department of Health Business Administration, Hungkuang University, 34 Chung-Chie Rd, Sha Lu, Taichung, Taiwan, R.O.C.
[4]Department of Information Management, National Sun Yat-sen University, Taiwan.
[5]Department of International Business and Trade, Shu-Te University, No. 59, Hun Shan Rd., Yen Chau, Kaohsiung, 824, Taiwan, R.O.C.

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The medical industry faces rapid changes and more competitive environment in recent years, so innovation has become the key element to improve competitive advantage for hospitals. We investigated the determinants of technological innovation and its influence on hospital performance through samples in Taiwan. We conducted a cross-sectional study and the data were obtained from four secondary databases: "Taiwan Hospital Annual", "Statistical Yearbook of the Interior" of the Taiwan Hospital Association, and "registry for contracted medical facilities" and "registry for contracted beds" of National Health Insurance Research Database in 2005. We adopted structural equation modelling to analyze our research model. We found that hospital scale affects technological innovation positively, the level of technological innovation of private hospitals is higher than that of public hospitals, and the technological innovation of non-teaching hospitals is also significantly higher than that of teaching hospitals. Results also showed that technological innovation influences ambulatory performance, emergency performance, and inpatient performance positively. This research confirmed that market factors failed to have a direct impact on the technological innovation of hospitals; hospital scale, hospital ownership and teaching status are the critical factors affecting technological innovation. Finally, we confirmed that technological innovation indeed affects hospital performance.

Key words: Technological innovation, ambulatory performance, emergency performance, inpatient performance positively, competitive advantage, medical industry, hospitals.

INTRODUCTION

For most successful organizations, consistent growth is the critical factor for success and innovation is the main driving force. Companies require sustained innovation of products, systems and services, which in every sector must become more responsive to customer demand, in order to compete successfully in the long-term (Schepers et al., 1999). Afuah (1998) states that innovation is an important resource for implementing novel knowledge to enhance organization's abilities, and develop new products as well as new services to create value in an organization. Hospitals are a knowledge-intensive and professional organization, therefore innovation is the key element in improving their environmental adaptability and competitive advantage (Mcdonald and Srinivasan, 2004). Accordingly, many hospitals have focused more on their development of innovation and have even invested more resources into enhancing their innovative performance.

*Corresponding author. E-mail: jahuang@vghtc.gov.tw. Tel: +886- 937212287. Fax: +886-4-23594065.

Researchers usually categorize organizational innovation into administrative innovation and technological innovation and it has been widely adopted by scholars of either organizational innovation or hospital innovation (Francesco, 2007; Goes and Park, 1997; Kimberly and Evanisko, 1981; Liao et al., 2008; Young et al., 2001). These two fundamental kinds of organizational innovation have different influences on organizational performance, therefore these two innovations must be considered independently when conducting research (Damanpour, 1991; Wolfe, 1994). Technological innovation enhances hospitals competitive advantages through the improvement of work efficiency and value (McDonald and Srinivasan, 2004). Moreover, it supports hospitals achieve core activities and enhance their reputations. Technological innovation is more directly related to the improvement of health care quality and for hospital managers it has become a key developmental component (McDonald and Srinivasan, 2004; Tsai and Li, 2002).

Based on the structure-conduct-performance (SCP) perspective of industrial organization theory, the characteristics of market structure affect the behaviour of organizations and subsequently cause different organizational performances (Hawawini et al., 2003). However, with regard to technological innovation, both market factors and organization factors are all main constructs that affect hospital technological innovation (Damanpour, 1991, 1996; Wang et al., 2005). In addition, some researchers have claimed that technological innovation can help to improve organizational performance (Damanpour and Evan, 1984; Torsten and Antonio, 2009). Nonetheless, little research has been done within hospital context based on a large-scale sample of hospitals. In order to fill the gap, our study collected large-scale secondary data from Taiwanese hospitals and aimed to investigate the determinants of hospital technological innovation from market and organizational aspects and examined the relationship between technological innovation and hospital performance.

LITERATURE REVIEW

Hospital technological innovation

Kimberly and Evanisko (1981) have defined hospital technological innovation as being directly related to diagnoses and treatment of disease, which can help hospitals to achieve the basic work activity or mission. They used twelve technological innovations items to measure technological innovation, including one surgical procedure, two new drugs, two new techniques and seven new kinds of equipment. Goes and Park (1997) define hospital technological innovation as the adoption of new medical technology and used six new medical innovations (laser surgery, ultrasound imaging, magnetic resonance imaging, fiberoptic endoscopy, cardiac catbeterization and computer axial tomography) to measure technological innovation. Wang et al. (2005) explored factors that affect the adoption of health information system in American hospitals, and measured hospital innovation by the adoption of three information systems, namely, clinical information system, administrative information systems and strategic information system. McDonald and Srinivasan (2004) stated that hospital technological innovation is a useful indicator of a hospital's product, service and production process, and they propose twenty items to evaluate hospital technological innovation. Mas and Seinfeld (2008) used thirteen medical technologies to explore how managed care restrains the development of technological innovation in hospitals. Chou et al. (2004) used the adoption of six expensive or dangerous medical devices to explore the effect of Taiwan's 1995 implementation of National Health Insurance on technological innovation. Weng et al. (2006) used the adoption of seventeen medical equipments to explore the diversity of technological innovation of hospitals.

According to the definition of hospital technological innovation, it focuses on the adoption of new and high-tech medical equipment. Dobrev et al. (2002) indicated that the adoption of new medical technology is an important competitive strategy for gaining a competitive advantage and for increasing a hospital's reputation. In a more competitive market, hospitals are more proactive in adopting high-tech medical equipment to enhance their competitive advantage (Bokhari 2009; Hillman et al., 1987; Teplensky et al., 1995). Since the adoption of high-tech medical equipment has been demonstrated to provide hospitals with a critical competitive advantage, many scholars have used high-tech medical equipment to define hospital technological innovation. Therefore, we adopted the same criterion to define hospital technological innovation. Hospital technological innovation in this study was defined as the function of new and high-tech medical equipments and systems which are adopted by each hospital and are directly related to diagnoses and treatment of disease.

The determinants of technological innovation

As we say in the last section of the introduction, the characteristics of market structure affect the behaviour of organizations and subsequently cause different organizational performances based on SCP paradigm of industrial organization theory. Many research use the SCP perspective to explore the determinants of the adoption of new medical technologies (Bokhari, 2009; Douglas and Ryman, 2003; Lo, 2005; Mas and Seinfeld, 2008; Robone and Zanardi, 2006; Tsai and Li, 2002). In addition, based on resource dependency perspective, organizational decision to deal with the needs of external customers or

other organizations will depend on how abundant and stable resources are in a given market environment. Under favourable market conditions, the organization may not feel constrained to respond to their needs. In addition, different characteristics of organizations would have influences on their behaviours to respond external environments which they depended on (Banaszak-Holl et al., 1996). Organizational characteristics also should be seen as critical factors affecting the organizational innovation (Hult et al., 2004). Dual core model of organizational innovation also supported the above-mentioned arguments (Daft, 1978). Damanpour (1991) further proved the effects of organizational factors on technological or administrative innovation by a meta-analysis.

Owing to the importance of market and organizational factors, many studies tried to collect empirical data to examine the effects of these two kinds of factors on technological innovation (Banaszak-Holl et al., 1996; Goes and Park, 1997; Kimberly and Evanisko, 1981; Naranjo-Gil, 2009; Sorensen and Stuart, 2000; Wang et al., 2005; Weng et al., 2006).

Therefore, after considering the limitations of secondary data and referring to previous research on technological innovation, we developed hospital age (Damanpour, 1991; Kimberly and Evanisko, 1981; Sorensen and Stuart, 2000), hospital scale (Banaszak-Holl et al., 1996; Damanpour, 1991; Davis et al., 2009; Goes and Park, 1997; Jaana et al., 2006; Wang et al., 2005), hospital ownership (Banaszak-Holl et al., 1996; Davis et al., 2009; Goes and Park, 1997; Jaana et al., 2006; Wang et al., 2005), teaching status (Mitchell et al., 2002; Wang et al., 2005; Weng et al., 2006), service complexity (Damanpour 1991, 1996; Kimberly and Evanisko 1981; Lo 2005; Wang et al., 2005), administrative intensity (Damanpour 1991; Salavou et al., 2004; Weng et al., 2006) as organizational factors in our model.

In addition, because market scale (Banaszak-Holl et al., 1996; Kimberly and Evanisko 1981; Naranjo-Gil 2009; Robone and Zanardi 2006; Wang et al., 2005) and market competition (Banaszak-Holl et al., 1996; Bokhari 2009; Kimberly and Evanisko 1981; McDonald and Srinivasan 2004; Naranjo-Gil 2009; Robone and Zanardi 2006; Wang et al., 2005) are two critical market factors affecting technological innovation in hospitals from the SCP and resource dependency perspective, we also included these two market factor in our study.

The impact of market factors

Whether there are sufficient profit incentives and customer demands in the market is a major factor which affects hospital technological innovation (Hawawini et al., 2003). It increases an organization's willingness to develop technological innovation when profit incentives and customer demands are adequate in the market. Hospital industry is a highly capital-intensive industry (McDonald and Srinivasan, 2004). Therefore, when there are high profit incentives in the market, hospitals are more highly motivated to invest substantial capital to improve technological innovation. Dranove et al. (1992) state that if an area has a high population, there will be more complex medical problems, so hospitals will be more likely to adopt and extend new medical technology. In addition, market uncertainty is positively linked to the volatility of market size. Organizations residing in relatively uncertain environments may be expected to adopt a greater number of innovations than those residing in relatively certain environments. Naranjo-Gil (2009) indicates hospitals are more likely to adopt innovations when there are more opportunities or uncertainties in the market. Wang et al., (2005) also found market size had a positive association with hospitals' adopting new technologies. Therefore, it is hypothesized that:

H_1: Market scale has a positive influence on technological innovation.

Hospitals will constantly evaluate their technological advantages and adopt newer technology to maintain their advantage in a highly competitive environment (McDonald and Srinivasan, 2004). Health care prices will be restricted by third-parties if hospitals apply a third-party payer system, and as a result, hospitals will dedicate more resources to improving healthcare quality rather than engaging in price competition. In a more competitive market, hospitals will be more willing to invest in high cost healthcare quality to attract patients and to increase market share (Bokhari, 2009; Tsai and Li, 2002). Based on the "medical arms race" theory, a hospital's motivation to purchase expensive high-tech medical equipment is positively associated with the degree of market competitiveness. Strategic contingency theory suggests that organizations can respond to hostility. Organizations in a competitive industry would constantly evaluate technologic advantages and adopt them in order to gain a competitive advantage. Thus, market competetiveness is significantly related to the adoption of new technologies (Wang et al., 2005). Goes and Park (1997) empirically showed that hospitals will adopt new medical technology to achieve a better reputation and to compete with other hospitals, and confirmed that market competition has a positive influence on hospitals' willingness to adopt innovation. Therefore, it is hypothesized that:

H_2: Market competition will have positive influence on technological innovation.

The impact of organizational factors

Hospital age

Research into organizational learning has revealed that an organization's innovative capacity is built on its

background knowledge base. The lack of sufficient background knowledge would impede organizational ability to develop and adopt innovations. Older companies tend to have a richer functional and productive knowledge base which can enhance the organization's ability to exploit innovation and improve the diverse developments of technological innovation (Cohen and Levinthal, 1990). Older organizations will have perfected the routines, structures, incentive programs, and other infrastructure that are needed to develop or adopt new technologies and bring them to market (Sorensen and Stuart, 2000). Thus, organizations which have survived a long period of time are likely to develop the capability to innovate. Moreover, studies on organization ecology researchers showed that due to the shortage of formal structure and institutional legitimacy in new organizations, firms are inefficient in developing innovation, resulting in so-called "liability of newness" (Freeman 1990; Weng et al., 2006). Kimberly and Evanisko (1981) investigated technological innovation and found hospital age was significantly associated with the level of hospital technological innovation. Therefore, it is hypothesized that:

H_3: Technological innovation will be positively influenced by hospital age.

Hospital scale

From the perspective of resource shortage, larger organizations have more complex resources and ability, better technical know-how and can adopt diverse innovations (Weng et al., 2006; Young et al., 2001). Damanpour (1987) indicated that large organizations have more diverse and more complex facilities that presumably foster the adoption of a larger number of innovations. On the other hand, according to diffusion of innovation theory, hospitals need sufficient resource to support, accomplish and maintain the adoption of new technology (Wang et al., 2005). Some researchers have also reported that larger hospitals may have greater access to the resources and critical mass needed to develop technological innovation (Goes and Park 1997; Kimberly and Evanisko 1981). Larger organizations have more resources available and are better equipped to develop, evaluate, and implement new technologies (Wang et al., 2005). Larger hospital scale is directly related to medical demands and number of patients and larger hospitals can enjoy the benefits of economy of scale. Thus, larger hospitals are more likely to adopt or extend new medical technology (Kimberly and Evanisko, 1981). Lo (2005) indicated that bigger hospitals have more resources, higher ability and higher internal demand, and therefore they are better able to adopt new medical technology. In addition, larger organizations have more complex structures and face more uncertainties that would necessitate their adoption of innovations (Jaana et al., 2006).

Chou et al. (2004) also found hospitals with more beds are more likely to adopt technologies. Naranjo-Gil (2009) confirmed that the adoption of technological innovation was positively significantly related to hospital size. Therefore, it is hypothesized that:

H_4: Hospital scale will have positive influence on technological innovation.

Hospital ownership

Missions of organizations may affect strategic actions and decisions to innovation development and adoption. For-profit organizations are presumably the most market-oriented providers and would have higher incentives to introduce new services and technologies that attract more consumers (Banaszak-Holl et al., 1996). Unlike public hospitals, private hospitals do not have financial support from the government, hence they have higher residual claimants to provide incentives for profit and further development, which spurs technological innovations and activities (Kimberly and Evanisko 1981; Young et al., 2001). However, public hospitals have the financial support of the government and have to take numerous policy-related responsibilities into consideration. Consequently, public hospital managers generally adopt a conservative and stable policy (Milgrom and Roberts 1992). Price (1992) noted that a high level of bureaucracy and lack of rapid reaction to market conditions lowers hospitals' innovation in healthcare. Compared with public hospitals, private hospitals have greater strategic flexibility, higher environmental sensitivity and higher demand for promoting market status (Goes and Park 1997). Hisashige (1994) found the amount of high-tech medical equipment in private hospitals was more than in public hospitals.

Barros (2003) compared two hospitals and found the private hospital performed better than the public hospital because of the differences in technology. Private hospitals are wholly responsible for organizational performance in a competitive environment, hence they adopt or extend new medical technology proactively (Rajshkha et al., 1991). Chou et al. (2004) confirmed that private hospitals have more probability to adopt new technology. In addition, Wang et al. (2005) reported that the adoption of an innovative information system in public and private hospitals was significantly different. For nursing homes, Davis (2009) indicated that for-profit ones were more efficient than were nonprofits and for-profits will use more new technologies than nonprofits. Therefore, it is hypothesized that:

H_5: Technological innovation of private hospitals is significantly higher than one of public hospitals.

Teaching status

Hospitals in Taiwan can be categorized into teaching hospitals and non-teaching hospitals. Hult (2004) found learning orientation is positively related to organizational innovativeness. Teaching hospitals would pay much importance to employee learning and organizational learning to improve the level of learning orientation. Furthermore, teaching hospitals offer their facilities to doctors and health care personnel or to medical school students for medical education and training (Weng et al., 2006). Therefore, teaching hospitals which have a higher level of teaching and research will dedicate more resources to research. Mitchell (2002) found that the utilization rate of high-tech equipment, that is, CT and MRI, was higher in teaching hospitals than in non-teaching hospitals. According to absorptive capacity theory described by Cohen and Levinthal (1990), if an organization invests more resources in R&D it will increase its own absorptive capacity. The improvement of the absorptive capacity is the essential factor affecting the adoption of innovation technology in organizations (Keller, 1996). In addition, with the improvement of the absorptive capacity, the technological knowledge resources in the organization would also be enriched (Chen, 2004). Damanpour (1991) indicated that the greater the technological knowledge resources, the more easily can new technical ideas be understood and procedures for their development and implementation be attained. Therefore, it is hypothesized that:

H_6: Technological innovation of teaching hospitals is significantly higher than one of non-teaching hospitals.

Service complexity

Service complexity is the number of clinical specialties in a hospital: when a hospital has more specialties it means that its medical sectors have higher functional differentiation, which will increase the hospital's structure complexity and medical service complexity (Damanpour, 1991; Eiriz et al., 2010; Young et al., 2001). Damanpour (1996) showed that in an organization with a high structure complexity, different specialists can offer more diverse knowledge bases to improve the exchange and diffusion of creative ideas, and induce more diverse creative innovations. If hospitals' functional differentiation is higher, it will have diverse interest groups and demands of core technology, which will serve to further advance hospital technological innovation (Kimberly and Evanisko, 1981). Damanpour (1991) used the meta-analysis method to found that functional differentiation would highly influence the adoption of innovations and is also positively related to technological innovation. Therefore, medical service complexity is a vital factor in the adoption of hospital technological innovation (Young et al., 2001). Lo (2005) found that if the hospital has more specialties it will have more resources, capability and higher internal demand, and will be better able to adopt or extend new medical technology. Therefore, it is hypothesized that:

H_7: Service complexity has a positive influence on technological innovation.

Administrative intensity

Hospital administrators often have more interests on any kind of innovations that could improve organizational efficiency or effectiveness (Kimberly and Evanisko, 1981). Therefore, administrative intensity of a hospital may be the factors affecting the adoption of innovations. If an organization has higher administrative intensity (the percentage of management employees), it can execute the related management functions efficiently while developing innovation (Damanpour, 1996). Salavou et al. (2004) indicated administrative intensity is an important determinant of organizational innovation and use the ratio of administrative worker to total employees. Damanpour (1991) and (1987) pointed out that a higher administrative intensity would facilitate innovation because the successful innovation depends largely on the leadership, support, and coordination managers provide. In hospitals, high administrative intensity will increase hospital adaptation of new technology and new techniques from the external environment (Weng et al., 2006). Therefore, it is hypothesized that:

H_8: Administrative intensity has a positive influence on technological innovation.

The impact of technological innovation on hospital performance

The purpose of organizational innovation is to advance organizational performance by maintaining organizational competitiveness: organizations can develop innovation through the systems of input, output, transformation and feedback (Didier and Guerreror, 2002). First-mover advantage research shows that industry innovators can usually achieve first-mover advantage, including technology, resource pre-emption, switching cost, decision uncertainty and create higher economic profit (Lieberman and Mentgomery, 1988). From resource-based view, innovation is a means for changing an organization, whether as a response to changes those occur in its environment or as a pre-emptive move taken to influence an environment. Because environments evolve, organizations must adopt innovations over time and the most important innovations are those that allow the firm to achieve some sort of competitive advantage, thereby

contributing to its performance (Hult et al., 2004). The development of technological innovation is benefits organizations by creating valuable, rare, imperfectly imitable and non-substitutable resources, thus improving organizational advantage and performance (Barney and Burnham 1991).

Yamin and Gunasekaran (1999) hold that innovation can be improved through technology to reduce production cost. Furthermore, organizational productivity as well as overall performance will benefit from innovation. Their empirical investigation of Australian manufacturing companies showed that the organizations with a higher degree of technological innovation had a higher performance in marketing, asset management, production effectiveness and financial performance. Hagedoorm and Cloodt (2003) found that technological innovation has a positive impact on organizational performance in 1200 international organizations. In the health care industry, Irwin et al. (1998) used a sample of 189 hospitals in Florida and discovered a positive relationship between medical technological innovations and hospital financial performance. Salge and Vera (2009) investigated 173 English public hospital organizations and found hospitals investing in innovation-generating activities can enhance clinical performance. Eric et al. (2007) studied 111 hospices in California and found that innovative practices were positively related to quality of care. The residents who were most able to afford palliative care cost were more accepting of innovative practices and could help to improve hospices' performance.

Naranjo-Gil (2009) proved that the adoption of technological innovation was positively related to organizational performance in Spain's public hospital sector. A study on English public acute care organizations suggests that technological innovation helps knowledge diffusion and clinical treatment innovation. In addition, patients had more confidence in treatment, therefore, technological innovation had a significant positive influence on both clinical performance (patient death rate, satisfaction and service quality) and administrative performance (net profit, income per bed and resource use rating) (Torsten Oliver and Antonio 2009). Thus, we propose the following hypotheses:

H_9: Technological innovation has a positive influence on ambulatory performance.

H_{10}: Technological innovation has a positive influence on emergency performance.

H_{11}: Technological innovation has positive influence on inpatient performance.

METHODS

Research framework

We developed 11 hypotheses which are needed to be examined by the empirical analysis through reviewing previous theories and researches. Based on the statements of hypotheses which are developed in the section of literature review, we proposed a research framework, shown in Figure 1. Figure 1 indicated that the study tried to examine the effects of two market factors and six organizational factors on technological innovation and the association between technological innovation and three kinds of hospital performance.

Data source and collection

The major data source of the study was the "2005 Taiwan Hospital Annual" published by the Taiwan Hospital Association, which contains data on 299 Taiwanese hospitals. Our analysis included data from 217 hospitals of these hospitals. The remaining 82 hospitals were excluded due to incomplete data. As for hospital locations, Goodness of fit test showed no significant difference between populations and samples ($p > 0.05$). In addition, we also obtained data from the "2005 Statistical Yearbook of the Interior", "registry for contracted medical facilities" and "registry for contracted beds" of the National Health Insurance Research Database in 2005.

The operational definition of research variables

According to the measurement items proposed by Weng et al. (2006), Goes and Park (1997) and Kimberly and Evanisko (1981), we adopted 16 high-tech medical equipment items to evaluate technological innovation. The operational definition of technological innovation for each hospital is:

$$\sum_{i=1}^{16} i_{\text{total number of equipment}} \times i_{\text{the weight of equipment's innovativeness}}$$

Equipment items and the weight of their innovativeness are shown in appendix.

The operational definitions of other variables are as follws: 1. Market scale: the logarithmic value of populations in every city at the end of 2005; 2. Market competitiveness: measuring by Herfindahl-Hirschman Index (HHI) (Scherer 1980), HHI is given by the formula $\sum_{i=1}^{n}(\alpha_i)^2$, where αi is the market share of each hospital in the same city, calculate in terms of the number of hospital beds in 2004; 3. Hospital age: (2005)−(The year of establishment); 4. Hospital scale: the logarithmic value of employees in the hospital at the end of 2005; 5. Hospital ownership: including public and private hospitals in 2005; 6. Teaching status: Teaching hospitals and non-teaching hospitals in 2005; 7. Service complexity: the number of specialists, twenty-eight specialists in total by the end of 2005; 8. Administrative intensity: the percentage of administrative personnel in all employees in 2005.

Hospital performance is a diverse construct, so there is no single index which can cover a hospital's whole performance (Gruca and Nath, 1994). Previous studies have used different measurements to assess hospital performance, for instance, Valdmanis (1990) used number of acute inpatient days, number of surgeries, intensive care unit days, and number of ambulatory plus emergency room visits to evaluate hospital performance in Michigan; Magnussen (1996) used inpatient activity for patients with a limited length of stay, the number of patient days in long-term care and the number of outpatient visits to evaluate hospital efficiency in Norway; Linna (2000) used total sum of schedule and follow-up visits, total number of emergency visits, number of admissions and bed-days to evaluate the performance of acute care hospitals in Finland; Harrison (2005) used inpatient days, the number of surgical procedures and outpatient visits to measure the efficiency of veterans health administration hospitals in America. Based on the aforementioned evaluation methods, we classified hospital services into three categories, namely, outpatient service, emergency service and

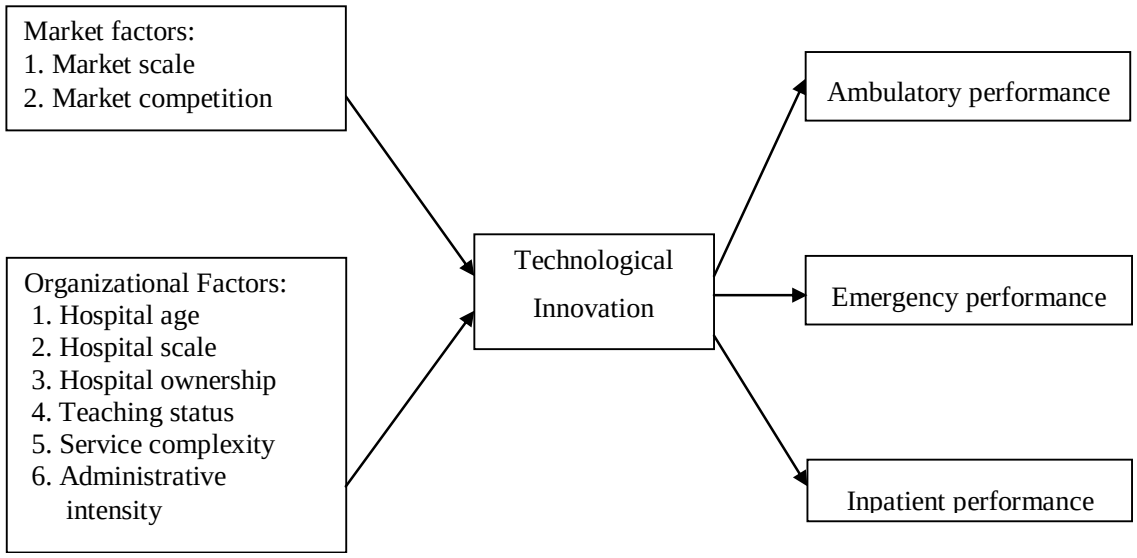

Figure 1. Research framework.

inpatient service. Subsequently, we used ambulatory performance, emergency performance and inpatient performance to evaluate hospital performance. Due to limited secondary data, we used daily outpatient visits (the total number of outpatient visits in 2005/270 days) to represent ambulatory performance, daily emergency visits (the total number of emergency visits in 2005/365 days) to represent emergency performance, and occupancy rate of acute beds [(the sum of inpatient days in 2005/365 days) /current beds in 2005 * 100)] to represent inpatient performance.

Analysis method

Besides using prescriptive analysis to delineate sample characteristics, we also used a correlation matrix to test correlations among the various constructs. We found that all distributions of daily outpatient visits, daily emergency visits and occupancy rate of acute beds were skewed to the left.

The research framework was evaluated by partial least squares (PLS), which is one kind of approaches to structural equation modelling (SEM). PLS is a second generation technique for the estimation of path models which allows to identify multiple dependent variables simultaneously (Chin et al., 2003; Naranjo-Gil, 2009; Smith and Bristor 1994). King and Lekse (2006) indicated that PLS possesses certain advantageous characteristics which include allowing smaller sample size, allowing samples without normal distributions, explaining dependent constructs efficiently, and being able to deal with complex causal relationships. However, PLS does not provide on the fit of the whole model, we applied R2 to stand for the fitness, where higher R2 means better fit (Chin et al., 2003). The estimated path coefficients between constructs are standardized regression coefficients which indicate whether hypotheses match or not (Smith and Bristor, 1994). The program Smart PLS 2.0 was used to analyze research data.

RESULTS

The valid sample included 217 hospitals, of which 77.88% were private hospitals and 59.45% were non-teaching hospitals. In addition, the mean of hospital market scale was 13.93 (SD = 0.83), market competitiveness was 964.45 beds (SD = 664.78), average year was 26.52 year (SD = 22.35), hospital scale was 5.38 (SD = 1.35), service complexity was 12.1 (SD = 8.48), administrative intensity was 21.87% (SD = 23.42), daily outpatient visits were 1015.66 persons (SD = 1454.80), daily emergency visits were 61.65 patients (SD = 22.72), occupancy rate of acute beds was 60.56 beds (SD = 22.72), number of inpatient days of acute beds was 18.81 days (SD = 61.90), technological innovation was 129.53 (SD = 276.62). The correlation analysis result is shown in Table 1. Table 2 shows technological innovation, ambulatory, emergency and inpatient performance of teaching hospitals were significantly higher than in non-teaching hospitals.

Before we performed PLS analysis, the re-sampling times was set as 500 which suggested by Chin (1998) to test whether each path was significant or not. PLS analysis result revealed that technological innovation (R2 = 0.45) is positively influenced by hospital scale (β = 0.95; t = 7.50) and the level of technological innovation in private hospitals was higher than in public hospitals (β = 0.15; t = 3.01). On the other hand, market scale, market competitiveness, hospital age, teaching status, service complexity and administrative intensity had no significant influence on technological innovation.

Surprisingly, our empirical result showed teaching status was negatively related to technological innovation (non-teaching hospital > teaching hospital). As for the impact of technological innovation on hospital performance, PLS result showed ambulatory performance (R2 = 0.66), emergency performance (R2 = 0.52), and inpatient performance (R2 = 0.10) were all positively related to technological innovation, with β and t values of 0.81, 19.39; 0.72, 15.18 and 0.31, 9.31, respectively (Figure 2). In conclusion, our hypotheses H_4, H_5, H_9, H_{10}

Table 1. Correlations analysis between each construct

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10
Market scale	13.93	0.83	1.00									
Market competitiveness	964.45	664.78	-0.78**	1.00								
Hospital age	26.52	22.35	-0.15*	0.10	1.00							
Hospital scale	5.38	1.35	0.02	0.06	0.28**	1.00						
Service complexity	12.10	8.48	-0.06	0.12	0.31**	0.90**	1.00					
Administrative intensity	21.87	23.42	-0.04	-0.02	-0.06	-0.22**	-0.10	1.00				
Daily outpatient visits	1015.66	1454.80	0.08	0.01	0.16*	0.76**	0.65**	-0.10	1.00			
Daily emergency visits	61.65	93.01	0.05	0.06	0.16*	0.75**	0.65**	-0.08	0.92**	1.00		
Occupancy rate of acute beds	60.56	22.72	0.08	-0.01	0.05	0.48**	0.32**	-0.03	0.39**	0.38**	1.00	
Technological innovation	129.53	276.62	0.04	0.02	0.10	0.63**	0.53**	-0.09	0.81**	0.72**	0.31**	1.00

Note: ** $p < 0.01$; * $p < 0.05$

Table 2. Technological innovation and performance in hospitals based on teaching status and ownerships.

Variable	Technological innovation		Ambulatory performance		Emergency performance		Inpatient performance	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Teaching status								
Non-teaching	26.21	44.96	299.98	299.77	15.19	19.9	53.27	24.55
Teaching	280.98	384.67	2064.79	1817.74	129.76	114.03	71.25	14.16
Ownership								
Public	132.23	216.77	1061.31	1144.17	64.23	63.81	62.1	19.93
Private	128.76	291.94	1002.7	1534.32	60.92	99.91	60.13	23.49

and H_{11} were all supported by these findings; however, H_1, H_2, H_3, H_6, H_7 and H_8 were not supported.

DISCUSSION

The determinants of hospital technological innovation

Regarding market factors, we expected that the larger the market scale was, the higher the demand of medical technology, and hospitals would therefore have a higher profit incentive to enhance its technological innovation. We used a logarithmic value of population in each city to represent the market scale and determined that there was no significant association.

Lo (2005) found that population in each city did not significantly influence the adoption and expansion of new medical technology. Weng et al. (2006) also found that market scale had no significant influence on the diversity of technological innovation in Taiwanese hospitals.

Concerning market competitiveness, we estimated when the market was more competitive, hospitals would adopt newer technology to maintain their technological advantages. However, we used Herfindahl-Hirschman Index to measure hospitals' market competitiveness and found no significant associations. Tsai and Li (2002) found market competitiveness was positively related to the adoption of high-tech medical equipment, although Lo (2005) and Weng et al. (2006)

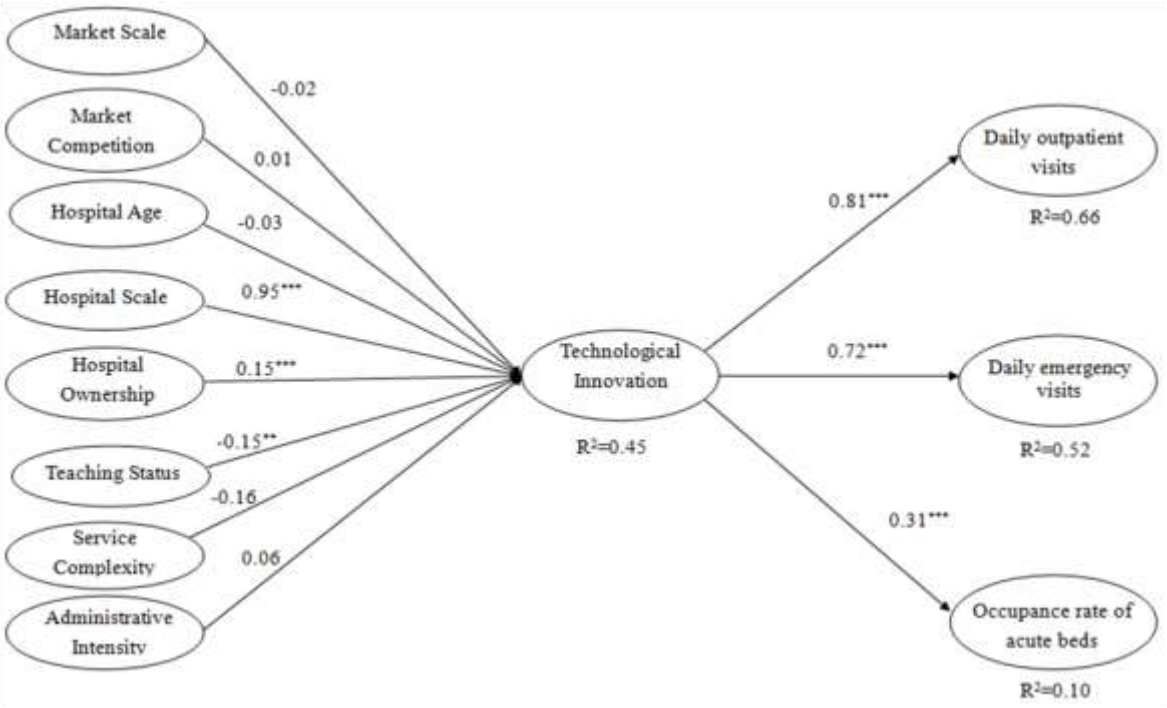

Figure 2. Results from Smart PLS analysis (path coefficients).
Note: The significant test of path coefficients is followed by Bootstrapping, re-sampling times are 500. ***means p < .001; **means p < 0.01

reported that market competitiveness was not significantly related to the adoption of high-tech medical equipment or the diversity of technological innovation.

Wang et al. (2005) also found the increase of market competitiveness had no influence on the adoption of an innovative information system. Based on our results, market factors failed to have a direct impact on technological innovation of hospitals, No matter how big market scale is or how high market competition is, hospitals in Taiwan still see organizational characteristics as critical factors (including: resource capabilities, for-profit orientation, and teaching status) when evaluating the adoption of technological innovations. Market factors may not be direct determinants of organizational innovation but they may be the contingency factors according to the contingency model of organizational innovation proposed by Damanpour (1996).

Therefore, although our results revealed that market scale and competition had no direct impact on technological innovation, the potential moderating role of market scale and market competition still cannot be ignored. Weng (2006) also approve that market competition would positively moderate the relationship between hospital age and the diversity of technological innovation. Concerning organizational factors, unexpectedly, the empirical result showed no significant relationship between organization age and technological innovation. Although previous research demonstrated that hospital age was positively related to technological innovation (Kimberly and Evanisko, 1981), Weng et al. (2006) showed no significant relationship between hospital age and the diversity of technological innovation.

Accordingly, the impact of organization age on the technological innovation of a hospital appears to be very limited. Sorensen (2000) indicated that when compared with young companies, older firms will show a greater tendency to develop innovative activities. This shows that environmental characteristics may moderate the impact of hospital age on organizational innovation. Weng et al. (2006) also found that hospital age could not affect the diversity of technological innovation directly but hospital age would have the significant influence on it through the moderate effect of market competition. Therefore, the impact of hospital age depends on the external environment where the hospital located in.

As for hospital scale, based on a study by Weng et al. (2006), we used the logarithmic value of the number of employees in a hospital to represent hospital size and found that size was positively associated with hospital technological innovation. Goes and Park (1997), Chou et al. (2004) and Weng et al. (2006) also proved that hospital scale was positively related to technological innovation. During the process of enhance technological innovation, hospitals need to pay much cost to adopt new medical technologies. Compared to small hospitals, larger ones have more resources and abilities to afford it. In the view of knowledge bases, larger hospitals can adopt diverse innovations because of better technical

know-how and a diverse knowledge background. Moreover, large organizations have more diverse and complex facilities and face more uncertainties that would foster the adoption of a larger number of innovations on the demand side. Therefore, it is thus clear that larger scale is really one critical factor when we explored the development of technological innovation.

As for ownership, we assumed that private hospitals were more strategically flexible, had high environmental sensitivity, and higher residual claimants to gains, and that these characteristics were beneficial for seeking and fulfilling innovative opportunities. In addition, because public hospitals generally adopt a conservative and stable policy and lack of rapid reaction to market conditions, they have lower motivation to foster technological innovativeness. The result supports the hypothesis that technological innovation of private hospitals was higher than that of public hospitals. Goes and Park (1997) and Hisashige (1994) found that the development of innovation was more favourable in private hospitals. In Taiwan, Lo (2005), Chou et al. (2004), and Weng et al. (2006) also found private hospitals have higher incentives to adopt innovative medical technology. Thus, in Taiwan and overseas, technological innovation of private hospitals is significantly higher than that of public hospitals, and the strategic flexibility, environmental sensitivity and residual claimants to gains in private hospitals are positively related to technological innovation.

For teaching status, we supposed that organizations investing more resources in R&D would have a higher level of technological innovation. Surprisingly, the results showed a negative relationship between teaching status and technological innovation. However, Weng et al. (2006) found that the diversity of technological innovation of teaching hospitals was better than that of non-teaching hospitals. Thus, early adopters of each technological innovation item should be rated more innovative. The negative relationship may have been the cause of we were not able to evaluate the adoption time of technological innovation items. Chou et al. (2004) found public teaching hospitals has longer managerial decision process and slower technology diffusion rate after Taiwan's implementation of National Health Insurance because these hospitals' technology decisions are affected by their teaching mission and financial factors simultaneously, If researchers can obtain the adoption time of technological innovation items or overcome the limitation of data collection, the data will more accurately demonstrate whether non-teaching hospitals have a higher level of technological innovation than teaching hospitals.

In service complexity, we used the number of clinical specialties to measure service complexity of hospitals and found no significant relationships with technological innovation. Chou et al. (2004) examined the effects of National Health Insurance on technology adoption and found it was not significantly affect by the number of specialties. Nonetheless, Kimberly and Evanisko (1981) indicated that specialization was positively related to the adoption of innovative medical technologies. Lo (2005) noted that the number of specialties had a positive impact on the adoption and expansion of new medical technology. Weng et al. (2006) also indicated that the number of specialties had a positive impact on the diversity of technological innovation. The different results might also be due to different evaluating methods of technological innovation. Chou et al. (2004) used the adoption of six expensive medical devices, Kimberly and Evanisko (1981) used the adoption of twelve technological innovation items, whereas Lo (2005) used the sum of users of high-tech medical equipments and Weng et al. (2006) used Blau's heterogeneity index to measure the diversity of technological innovation. We thought that although hospitals with higher service complexity may increase their diversity of technological innovation, the medical technologies which that they adopted may not be highly newly and advanced. On the contrary, because the introductions of highly newly and advanced technologies always cost higher, higher needs of medical technologies would lead to lower the level of newness and advance of technologies which hospitals want to adopt in the case of limited resources. Therefore, service complexity has no significant impact on technological innovation as a result of the offsetting between positive and negative influences.

Regarding administrative intensity, we expected that if the organization had higher administrative intensity then the development of innovation could be implemented effectively; however, the result showed no significant relationship between administrative intensive and technological innovation. Weng et al. (2006) reported a similar result. Although successful innovation depends largely on the leadership, support, and coordination managers provide, managers may use their professional expertise to evaluate the cost-effectiveness of the adoption of technological innovations. Nevertheless, different managers may be trained by different domain knowledge. Thus, if a hospital has higher administrative intensity, there may be many have different opinions and interests on the adoption of technological innovations in its hospital. In the case of limited resources, different opinions and interests on the decision on technological innovations not only lower the speed of innovation adoption but also reduce the diversity of technological innovation. In addition, the motivation toward innovation and risk tolerance would also affect the employee innovative behaviours. Manager innovative behaviours would have critical impact on their decisions on innovation adoption. A hospital with higher administrative intensity means many managers with different motivation and risk tolerance in a hospital. Managers with lower motivation toward innovation and risk tolerance would have lower tendency to adopt newly and advanced medical technologies. On the contrary, managers with

higher ones would have higher intent to adopt newly and advanced technologies. In this way, administrative intensity has no significant impact on technological innovation as a result of the offsetting between positive and negative influences.

The impact of technological innovation

The results of PLS analysis showed that technological innovation influenced ambulatory performance, emergency performance and inpatient performance positively. Yamin and Gunasekaran (1999) indicated that innovation can be improved through technology and may further enhance productivity and performance. Hurley and Hult (1998) pointed out a higher level of innovativeness in a company will help to develop competitive advantages and achieve better performance. Thus, when hospitals strive to improve their performance, medical technological innovations could be seen as strategic assets (valuable, rare, imperfectly imitable and non-substitutable resources) from resource-based view (Irwin et al., 1998). Eric et al. (2007) and Torsten and Antonio (2009) found that technological innovation was positively associated with performance of healthcare organizations. Our results also support prior studies that technological innovation indeed has a positive influence on ambulatory, emergency and inpatient performance.

This shows that technological innovation not only have positive influences on one kind of clinical service performance, but also is beneficial for overall hospital performance. Thus, hospital innovation would lead to improvement in clinical and service quality, and sequentially result in better operational efficiency and effectiveness (Torsten and Antonio, 2009). It also can be seen from this that the strategy of medical arms race is still very important for hospitals. Improving their technological innovation should be considered as a critical strategic goal when they want to establish the competitive advantage and further enhance overall hospital performance.

In addition, PLS analysis showed that the impact of technological innovation on ambulatory performance is higher than that on other service performance. Therefore, improving technological innovation should be more important for hospitals which see ambulatory services as core services.

Conclusion

Our empirical findings confirm market scale and market competitiveness had no significant influence on technological innovation of hospitals; on the other hand, regarding organizational factors, only scale, ownership, and teaching status were positively related to hospital technological innovation. Moreover, technological innovation influenced ambulatory performance, emergency performance and inpatient performance positively.

Managerial implications

Prior studies have claimed that the characteristics of market structure affect organizational behaviour; however, our study yielded different findings. We found only organizational factors, including hospital size, ownership, and teaching status had a direct influence on technological innovation. The critical factors that affect technological innovation were an organization's own abilities or characteristics, rather than market factors. Our results indicated the larger the hospital was, the higher the level of technological innovation, and the better performance the hospital was. This finding might explain why small hospitals in Taiwan have faced business difficulties in recent years.

In Taiwan, the development of technological innovation of private hospitals fares better than in public hospitals. Our results revealed that technological innovation had a positive relationship with performance; hence managers at public hospitals can dedicate more resources to improving technological innovation in order to raise hospital performance. We found technological innovation of non-teaching hospitals was better than that of teaching hospitals and this result differed from results reported by Weng et al. (2006). This finding is worth studying further, through long-term observation and data collection to explore whether a hospital's investment of resources in teaching can result in a crowding-out effect and even cause an unfavourable impact on the improvement of performance. Hospital technological innovation can indeed affect ambulatory performance, emergency performance and inpatient performance. Therefore, the promotion of technological innovation is an important strategy that managers can apply to improve a hospital's competitive advantages.

Research implications

Our study confirmed that organizational factors were the critical factors affecting technological innovation and this supports the contingency model of organizational innovation proposed by Damanpour (1996). Industrial organization theory states that market factors affect organizational behaviour and further affect organizational performance; however, our results showed market factors had no significant influence on technological innovation, and failed to support the SCP model. This finding warrants further research. First-mover advantage theory and resource-based theory all point out that organization can generate first-mover advantage, competitive advantage and achieve better performance by improving innovation. As a result, our findings support first-mover advantage theory and resource-based theory in that technological innovation indeed has a positive impact on

hospital performance.

LIMITATION AND FUTURE RESEARCH

A limitation of this study was the use of secondary data. Further studies should be conducted with a questionnaire to include other effects of technological innovation. In addition, we only used three items to evaluate hospital performance, other measurements can be adopted in future research. Follow-up research could also include a longitudinal study to collect data from different times to explore the determinant of each factor more accurately. Due to the limitation of database, this study only used the adoption of medical equipment to evaluate hospital technological innovation. In the future, scholars could further include IT as measurement items of technological innovation. Based on the features of research data, we applied PLS as analysis method, future research could consider Frontier Analysis to examine the research model. Finally, we only investigated technological innovation in this study, future studies could employ more sophisticated measurements which would allow for greater depth of analysis of these constructs and provide a more comprehensive method of evaluating hospital technological innovation along with administrative innovation.

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Appendix 1. Innovativeness weight of technological innovation items

Equipment	Score
Excimer Laser Angioplasty System, ELAS	59
Implantable cardioverter defibrillator implantation, transvenous approach	59
Implantable cardioverter defibrillator implantation, thoracotomy approach	59
Coronary rotablator	58
Amplatzer Septal Occluder	68
Extracorporeal Shock Wave Therapy, ESWT	64
Computerized Tomography Scanner, CT	31
Magnetic Resonance Imaging, MRI	42
CT Simulator	50
Cyberknife	49
Brachytherapy	44
Nuclear Medicine Equipment	36
Positron Emission Tomography	66
Medical Cyclotron	57
Extracorporeal Shock Wave Lithotripsy, ESWL	26
Hyperbaric Oxygen Equipment	48

Note: Ten experts with practical experience in healthcare management were invited to perform the assessment of innovativeness weight. A 10-point scale was used to rate each item with 1 being the lowest level of innovation and 10 being the highest level of innovation. As a result, the sum of 10 experts' scores of each technological innovation item was the weight of its innovativeness.