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# The effects of asset specificity on maintenance financial performance: An empirical application of Transaction Cost Theory to the medical device maintenance field

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ABSTRACT

This study uses multivariate regression analysis to examine the effects of asset specificity on the financial performance of both external and internal governance structures for medical device maintenance, and investigates how the financial performance of external governance structures differs depending on whether a hospital is private or public. The hypotheses were tested using information on 764 medical devices and 62 maintenance service providers, resulting in 1403 maintenance transactions. As such, our data sample is significantly larger than those used in previous studies in this area. The results empirically support our core theoretical argument that governance financial performance is influenced by assets specificity.



## 1. Introduction

Medical equipment maintenance increasingly demands larger sums from hospital budgets, with services that are often outsourced, while the quality of maintenance services is pivotal for overall delivery of healthcare quality to patients. While in 1996 such contracts generated revenues of US$10 billion (Blumberg, 2004), the global medical devices outsourcing market is projected to reach US$42.6 billion by the year 2015, according to the Medical Devices Outsourcing: A Global Strategic Business Report published by Global Industry Analysts, Inc (GIA), indicating that this market is still growing (GIA, 2010). Yet the anticompetitive nature of the medical device maintenance market generates extreme inefficiencies in both cost and service quality, suggesting that while the industry continues to grow, service quality is not keeping pace with rising costs and sales volumes (Smithson & Dickey, 2004:136). In the quest to overcome these obstacles, the scientific literature has identified the collaboration between the healthcare and systems engineering fields as possessing great potential, and recent interdisciplinary studies have suggested interesting solutions to healthcare efficiency problems from engineering, operational research, and business management perspectives (Boyer & Pronovost, 2010; Friedman & Mitchell, 1991; Grossmann, Goolsby, Olsen, & McGinnis, 2008; Mahara, Bretthauerb, & Salzaruloc, 2011; Richman, Udayakumar, Mitchell, & Schulman, 2008).

In particular, fields such as industrial engineering, systems engineering, management and operations research, with vast experience in system design, analysis and implementation of solutions across a variety of industries have the potential to increase the effectiveness, safety, efficiency and value in a variety of healthcare scenarios and institutions (Kolker, 2011:9; Richman et al., 2008). Without the intention of listing all, management and operations research can help in a set of very common problems presented in the healthcare environment including: decision making, capacity, staffing, scheduling, and resource allocation. In order to deliver quality health services, not only is it important to guarantee qualified staff, availability of beds, etc., but also it is essential to undertake effective healthcare technology management (Lenel, Temple-Bird, Kawohl, & Kaur, 2005:3). Particularly, maintenance tasks are an essential part of technology management systems because depending on how well a piece of equipment is looked after, its expectancy life can be prolonged or cut short (i.e. the equipment is not safe anymore, and/or it costs more to repair it than to replace it). However, the variety of medical devices is huge, and the resource costs needed to maintain these devices in proper working condition are high. Thus, health care managers face an important set of questions: which modality should be used to perform the medical device maintenance tasks? In other words, do I outsource or internalize the maintenance tasks for medical devices?

Despite the demonstrated applicability of interdisciplinary approaches to other healthcare systems problems, the decision-

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making process for medical device maintenance outsourcing appears trapped in antiquated paradigms that generate tremendous inefficiency, contributing to these growing costs. This may be especially true in developing countries, where limited funds or a lack of confidence in the skills of in-house staff lead to the outsourcing of maintenance services, under the belief that narrowing the scope of in-house tasks will lead to cost-savings and improved quality. As a result, the outsourcing of medical device maintenance activities appears to be a growing trend in the healthcare industry, as hospitals increasingly outsource maintenance services and eliminate their in-house service staff (Blumberg, 2004; Cruz, Perilla, & Pabon, 2010: 144). The problem is not exclusive to the healthcare industry – according to a survey performed by Deloitte Consulting, 44% of respondents[2] indicated that they saw no cost savings in their outsourced activities, while only 34% of respondents were satisfied with the supplier's service quality (Landis, Mishra, & Porrello, 2005). This problem is compounded by the fact that maintenance outsourcing studies appear contradictory and incomplete (Assaf, Hassanain, Al-Hammad, & Al Nehmi, 2011; Benaroch, Webster, & Kazaz, 2012; Berradea, Cristiano, & Scarf, 2012; Garg & Deshmukh, 2006; Miguel & Rios, 2012; Shafiee & Chukova, 2013; Simoes, Gomes, & Yasin, 2011). For example, Miguel and Rios (2012) found particular deficiencies in the few existing studies on medical device maintenance outsourcing. They identified a cluster of papers that apply mathematical models to maintenance outsourcing problems, noting that while these models were proposed for specific industries, none was applied specifically to the maintenance outsourcing of medical devices (e.g. Asgharizadeh & Murthy, 2000; Jackson & Pascual, 2008; Lisnianski, Frenkel, Khvatskin, & Ding, 2008; Lugfigheid, Jardine, & Jiang, 2007; Murthy & Asgharizadeh, 1999; Murthy & Yeung, 1996; Plambeck & Zenios, 2000; Rahman & Chattopadhyay, 2007; Tarakci, Tang, Moskowitz, & Plante, 2006a, 2006b; Tarakci, Teyarachakul, & Tang, 2009). Further, they identified weaknesses in several papers that made critical assumptions that would fail to hold in real-world applications (e.g. assuming equipment does not become more likely to breakdown as it ages). In a second cluster of papers, identified as empirical-longitudinal studies of maintenance outsourcing problems, they found only five papers related to the performance measurement of medical device maintenance outsourcing (Cruz, Aguilera-Huertas, & Días-Mora, 2010; Cruz & Denis, 2006; Cruz, Perilla et al., 2010; Miguel, Barr, & Pozo Puñales, 2007; Miguel, Denis, & Sanchez, 2002). However, these papers do not mention any discussion about the managerial implications of the findings is non-existent, making it difficult to apply results in a meaningful way in terms of the make or buy making decision paradigm. Additionally, no empirical proposal whose research was grounded in management or strategic management theory dealt in detail with the issues related to maintenance outsourcing, nor did any specifically deal with the outsourcing of medical device maintenance (Macher & Richman, 2008; Shafiee & Chukova, 2013; Shelanski & Klein, 1995).

The goal of this study is to bring operational and management research principles to the problem of medical device maintenance outsourcing. More specifically, we aim to use Transaction Cost Theory (TCT) as the theoretical foundation for a model measuring the financial performance of internal and external governance structures, which may serve as an aid for hospital managers making medical device maintenance outsourcing decisions. Our goal is to provide insight into which governance structures[3] provide hospitals with the most control over the performance of medical device maintenance under a variety of conditions, and we believe that managers of clinical/biomedical engineering departments and healthcare managers will be the first benefit from this research.

Therefore, our research seeks to extend the literature on how the main variables of interest to TCT influence the financial performance of internal and external governance structures by applying TCT to an examination of outsourcing performance in the maintenance service industry for medical devices. To our knowledge, this is the first study to use a TCT framework to examine the factors that affect the financial performance of both external and internal governance structures for medical device maintenance, while measuring the impact of these variables on financial performance. We believe the novelty of our approach lies both in its theoretical contribution and its examination of previously unexplored relationships between maintenance financial performance and governance selection, while including several control variables in our model that have gone ignored in previous studies. For example, our analysis includes the level of technological complexity of medical equipment, equipment age relative to useful live (equipment obsolescence), the level of training provided to biomedical technicians, and the number of years of experience of maintenance service companies, etc. Thus, by examining new relationships impacting governance structure financial performance, while controlling for a variety of other variables, our model is a unique, integral, empirical study of maintenance financial performance.

On the other hand, while most empirical papers and literature reviews support the assertion that TCT considerations are determinants of governance choice, few empirical studies have demonstrated whether governance structure impacts performance. This is because performance measurement (i.e. cost-inclusive,[4] cost-exclusive[5] measures) should compare the performance of internal versus external governance structures Geyskens, Steenkamp, and Kumar (2006), which becomes problematic since performance of the selected governance structure is observed, while the performance of those governance structures not chosen are not observed (Masten, 1993; Masten, Meehan, & Snyde, 1991). Therefore, we agree with (Geyskens et al., 2006), that "greater effort to understand the influence of governance choice on performance is needed". While the relationship between performance and the important constructs of TCT have received increasing attention in recent years, this research seems to focus almost exclusively on financial indicators of performance, such as profit, sales growth, and firm mortality rates (Geyskens et al., 2006; Macher & Richman, 2008). We believe that part of the novelty of our approach lies in its operationalization of financial performance as maintenance service costs relative to the original cost of acquisition, a measure of service quality, as opposed to profitability. This approach allows us to measure the performance quality hazards of contract misalignment, which has especially important implications in an industry such as healthcare, where the existence of public sector hospitals makes profitability and firm mortality a less useful indicator of performance. Surprisingly, in doing so, we found that some of our results go against one of the most common assumptions in the medical device maintenance field: that externalizing maintenance services improves service quality (Blumberg, 2004: 144).

This paper is organized as follows: Section 2 presents a brief literature review, identifying the theoretical variables that affect different measures of performance (including financial) and the empirical support they have received, Section 3 presents the formulation of our hypotheses. Section 4 presents the research

[2] Respondents were senior leaders in their corporations and were significantly involved in the decision making processes of outsourcing in manufacturing, education, government, retail, medical, and finance industries.

[3] For example: Market (Classical Contracting), Trilateral Governance (Neoclassical Contracting), Bilateral or Unified Governance Structures. See theoretical framework section for more details.

[4] Measures that encompass the costs of generating performance, including: level and growth of profit.

[5] Measures that do not directly encompass the costs of generating performance.

methods, discussing the data sample and collection methods, indicators for the dependent and independent variables, bias control strategies, and the specifications for the statistical model. Section 5 presents the results, with a discussion of the statistical data analysis. Section 6 discusses the theoretical impact and managerial implications of this study. Section 7 describes the limitations of the study and recommendations for future research in this area. We present the conclusions in Section 8.

## 2. Theoretical framework

The assumption and the theoretical core argument of our research is that the performance of maintenance governance structures (e.g. outsourced, or not outsourced with different degrees of integration, hybrid or discrete forms) is influenced by the features of the medical devices under their charge (e.g. equipment type, level of obsolescence, and technological complexity), and the hospital type on which maintenance service is provided (i.e. public or private). Specifically, these factors are influenced by the capacity of the firm to deliver the service, dependent on the firḿs physical and human resources features (i.e. assets specificity). TCT aims to identify which governance structure maximizes performance (e.g. efficiency) for a given firm (Alaghehband, Rivard, Wu, & Goyyette 2011). The governance mode refers to the degree of integration a firm selects to produce goods or services, i.e. market, hybrid, or hierarchical (Williamson, 1979). According to Williamson (1979) the market structure is the lowest degree of integration, while using hierarchical structures shows the highest degree of integration; therefore, hybrid governance structures fall somewhere in between (Williamson, 1979). According to TCT the ultimate unit of analysis is the transaction, while transactions are distinguished from one another through the resources (e.g. specific investment on machinery or tooling, spare parts, etc.) and activities (e.g. searching for supplier, negotiating contracts, monitoring) that are used to carry them out, and the frequency with which they occur. According to Williamson (1979) the most important attribute of transactions is asset specificity, understood as "the degree to which the assets used to conduct an activity can be redeployed to alternative uses and by alternative users without sacrifice of productive value" (Williamson, 1996:105). As such, asset specificity is used as the main focus of our paper for analyzing the transaction costs in the medical device maintenance industry.

Also, TCT posits that managers should decide on which governance choice is more appropriate to "align the transactions with governance structure in a discriminating way". Therefore, firms must choose an appropriate degree of integration in the governance structure in order to achieve adequate performance, considering not only the different capabilities of firms to produce a good or service but also to adapt to environmental disturbances (Crook, 2005: 16). For example, TCT predicts that more integrated governance structures show higher performance with a high degree of assets specificity. According to Williamson (1979), under these circumstances, using more integrated governance structures reduces the possibility of opportunism. Instead, market or hybrid governance structures are ideal when highly specific assets are not present, because firms can redeploy assets easier and/or identify alternative suppliers without high search and switching costs, economizing on transaction costs, and thus, improve performance under these conditions.

### *2.1. TCT and Empirical evidence for the effect of assets specificity on governance choice and firms' performance: A brief literature review*

In this research we will focus on the effect of asset specificity on governance choice and firms' performance. According to Williamson, assets specificity represents the most important transaction variable, it is defined as "the degree to which the assets used to conduct an activity can be redeployed to alternative uses and by alternative users without sacrifice of productive value," and notes that transactions involving highly specific assets are particularly ripe for opportunistic behavior on the part of either agent or principal. For example, if the agent makes investments in non-substitutable, highly specific assets that the agent is unable to easily find elsewhere, there may be incentives for the agent to engage in opportunistic behavior, as the power dynamics of the exchange relationship have shifted in their favor. At the same time, if an agent makes highly specific asset investments to provide a good or service for which the number of alternative buyers is limited, the principal holds significant power in the exchange relationship. To encourage such investment and mitigate opportunism, appropriate governance structures must be chosen (Williamson, 1979). Since, assets specificity represents the most important transaction variable it has been the most scrutinized and empirically tested of these variables, in studies spanning several fields, including business and non-business areas (e.g. law and public policy, health economics and policy, agricultural economics policy) (Macher & Richman, 2008; Roberts and Han, 2004; (Shelanski & Klein, 1995).

In an extensive review of approximately 900 articles that applied empirical tests to some aspect of TCT, Macher and Richman (2008) found significant support for the main predictions of TCT. Two main approaches to the empirical assessment of the effects of assets specificity[6] on a firm's activity divide the existing research: one approach has been to examine the influence of assets specificity on the governance selection, while other research has focused on the influence of assets specificity on the performance of both the organization and the governance structure chosen (Macher & Richman, 2008; Roberts and Han, 2004; Shelanski & Klein, 1995). In the first stream, specifically studying the effects of assets specificity on vertical integration, (Monteverde & Teece, 1982), along with the subsequent works done by Masten (1984), Masten, Meehan, and Snyder (1989) and provide the first evidence that asset specific investment is a critical determinant of vertical integration decisions. Furthermore, other empirical studies applied to different industries (e.g. sales, semiconductor research and development, and information technology) show that boundary choices possess distinctly different capacities to govern transactions. Regarding assets specificity, these studies have supported the idea that assets specificity has a strong, statistically significant, positive effect on internal governance structures (Anderson and Schmittlein, 1984; Anderson, 1985; Anderson & Coughlan, 1987; Lee & Lim, 2003; Leiblein & Miller, 2003; Lyons, 1995; Murray & Kotabe, 1999; Shelanski, 2004; Spiller, 1985; Ulset, 1996).

While there is considerable empirical literature examining the determinants of governance selection, much less attention has been given to the effects of TCT constructs and governance choice on performance chosen (Macher & Richman, 2008; Roberts and Han, 2004; Shelanski & Klein, 1995). In one of the few examples focused on the effects of assets specificity on governance performance, Poppo and Zengert (1998) conducted a data-survey study with 152 top computer executives in the information technology industry. They found that when assets specificity increases, internal governance structures showed advantages over external governance with respect to performance, measured by customer satisfaction. Similar results have been found by Espino-Rodriguez and Padron-Robaina (2006) in the hotel. Similarly, (De Vita, Tekaya, & Wang, 2010) tested the effects of the individual dimensions of

[6] We will focus solely in our explanatory logic and literature review on assets specificity, as the scope of our paper is limited to this aspect of TCT.

assets specificity on outsourcing performance in services-related industries[7] in the United Kingdom. This study examined the specific effects of the individual dimensions of buyer and supplier asset specific investments[8] on performance, proxied by the overall satisfaction of relational performance with service/product quality. The results of this study indicate that asset specific investments impact satisfaction with the outsourcing relationship performance and this effect varies according to the particular assets specificity dimension examined. Also, Nickerson and Silverman (2003) and Bigelow (2008, 2006) studied the effects of misalignment on a firm's survival time as a measure of performance, hypothesising that when misalignment increases, a firm's survival time decreases. However, these two studies produced contradictory results, with Nickerson and Silverman (2003) finding no statistically significant relationship between misalignment and firm survival time, while Bigelow (2006) found statistical evidence for this relationship. In another study Silverman, Nickerson, and Freeman (1997) analyzed the performance of more than 42,700 large and small motor carriers in the American interstate trucking industry, proxied by the firm mortality rate. The empirical study showed that firm mortality increases when it does not adhere to operating policies consistent with transaction cost minimization principles. Moreover, (Leiblein, Reuer, & Dalsace, 2002) investigated the technological performance implications of production internalization versus outsourcing in the semiconductor manufacturing industry. They found that firms' decisions to outsource or internalize production affect technological performance, proxied by transistor density,[9] consistent with TCT predictions. Another study conducted by Silverman (1999) studied the effects of a firm's human capital, as a measure of assets specificity, on the diversification of the firm, as an indicator of performance. They found that when the tacit knowledge associated with technological resources increases, the diversification of the firm also increases.

Again, we should notice that we found a small number of articles containing empirical research proposals evaluating the performance of medical device maintenance outsourcing in hospitals (Cruz, Perilla et al., 2010; Miguel et al., 2002, 2007; Cruz & Denis, 2006). Importantly, they operationalize performance in terms of service quality, in this case measured as the turnaround time for maintenance tasks. Still, they are limited in that they did not venture outside the characterization phase in the study, and in their discussion of the results there is no mention of management theory to sufficiently justify the research findings and managerial implications. Thus, it is not clear how these studies extend the literature on maintenance outsourcing (i.e. 'make or buy', theory of firm, etc.) in a meaningful way.

We should also note that it has been difficult to empirically support the effects of assets specificity on maintenance performance in the medical device field. All that we have is a vast array of anecdotal evidence and sample cases reported in the literature about medical device maintenance outsourcing experiences (Temple-Bird, Kaur, Lenel, & Kawohl, 2005a, 2005b, 2005c). However, because there is considerable empirical evidence in other fields that demonstrates that assets specificity has effects on both governance structure selection and governance performance there is reason to suspect that assets specificity also should have effects on the maintenance performance of the governance structure in the medical devices industry as well. Thus, while we operationalize performance differently than has been done in previous empirical investigations in TCT, we believe TCT should provide a theoretical framework to support our arguments that specific spare parts and diagnostic software, as measures of assets specificity, impact the maintenance financial performance of the chosen governance structure.

## 3. Hypothesis development

For the case of medical device maintenance, with performance measured as the financial performance for maintenance tasks, an indicator of service quality, we expect that an increase in assets specificity will decrease the performance of internal governance structures, relative to the financial performance of external structures.

In medical device maintenance, the repair of highly complex medical devices requires specific spare parts, which are costly to acquire and store, while the devices using these specific spare parts are limited, and significant uncertainty exists as to when – or if – a given spare part will be needed. As a result, the acquisition and storage of replacement parts of complex equipment represents a significant asset investment on the part of the service provider. At the same time, equipment spare parts and maintenance materials are essential because without them medical devices cannot be maintained or repaired, even if problems are easily fixable (Paton & Nyamu, 1996; Temple-Bird et al., 2005a:107). Consequently, if spare parts are not readily available, the medical equipment cannot be adequately maintained and the frequency of breakdowns increases, provoking long periods of equipment downtime. This is particularly important in developing countries, where spare parts often must be ordered from abroad. The procurement of such spare parts from abroad is a lengthy and tedious process, because it may take a significant amount of time to obtain price quotes and ship goods (Cruz, Aguilera-Huertas et al., 2010; FAKT, 1997; Halbwachs, 2000; Halbwachs & Temple-Bird, 1991; Ministry of Health, 2003). For example, Cruz, Perilla et al. (2010) found that the response time to bring critical spare parts to the maintenance site represents 80% of the overall turnaround time in corrective maintenance tasks. Based on this reasoning, we hypothesize that:

**Hypothesis 1.** The presence of idiosyncratic spare parts in the same city where serviced equipment is located has a positive impact on the financial performance in maintenance transactions of both internal and external governance structures.

The TCT states that more integrated governance structures should show performance advantages in transactions in which high degrees of specific asset investments are involved (i.e. idiosyncratic spare parts) (Williamson, 1979). Therefore, according to the TCT in the presence of transactions with highly specific asset the governance structures should be internalized (Williamson, 1979). However, while this may seem like an obvious decision with clear empirical evidence (Macher & Richman, 2008), and with clear subsequent implications for maintenance financial performance and service quality, the reality is often more complicated for the industry of medical device maintenance.

On one hand, a recent trademark United States court decision about Storz v. Surgi-Tech, signaled a new paradigm in the form healthcare institutions manages and conduct the repairs of medical equipment (Gordon, 2001). This case started when the Karl Storz Company began receiving complaints from users about the quality and performance of Karl Storz's rigid endoscopes. Since these endoscopes cost thousands of dollars, when they failed or were completed damaged, the hospitals and clinical engineering departments preferred to repair them rather than removed them from inventories. Therefore, hospitals in an effort to reduce costs they look to either the in-house service or independent maintenance

[7] Banking and finance, hotel, information technology, and telecommunication industries.

[8] Authors disaggregated the assets specificity measurement into various dimensions including: human, dedicated, site, temporal, brand capital and procedural assets specificity (De Vita et al., 2010).

[9] Transistor density represents a universally valued success factor. Therefore, it is the fundamental driver of both cost and product performance in the industry.

organizations to perform these maintenance tasks. In doing so, by the substitution of many specific spare parts during the maintenance tasks, the repairers had created poorly rebuild versions of the original equipment (i.e. Karl Storz's endoscopes), which affected the company reputation, when equipment become to fail unexpectedly. In other words, it was a case of the solution being worse than the problem.

On the other hand, it has been reported that, the performance of corrective and/or preventive maintenance of medical devices might be lower if service providers use different or alternative corrective and/or preventive maintenance methods from those specified by the original equipment manufacturers (De Vivo, Derrico, Capussotto, & Reali, 2004). For example, using a cheaper part instead of an original equipment manufacturer part might not be cost-effective in the longer term (Deparment of health., 2006: 44). In addition to that, there is a trend of thought in the field of clinical engineering (even one could also share this thought) that as maintenance service needs more specialized spare parts, the in-house service costs rise up (i.e. lower financial performance). Logically, the service external governance maintenance structures (mainly original equipment manufacturer) have a competitive advantage over in-house modality because they have the ability to synchronize idiosyncratic spare parts purchase and locate them in a better way and also, they have better economies of scales to perform the maintenance tasks, resulting in a lower maintenance service costs (i.e. better financial performance) (Cram, 2002). Based on this reasoning, we hypothesize that:

**Hypothesis 1a.** The presence of idiosyncratic spare parts in the same city where serviced equipment is located has a stronger positive effect on financial performance of the maintenance transactions of external governance structures than internal governance.

An additional, pertinent example of highly specialized assets in the medical device maintenance field is online ancillary support service. In the second case, it is clear that there is a high demand for ancillary support services such as remote diagnostics, and online parts management among users of medical technology, particularly for high complexity equipment (Blumberg, 2004: 142). These technologies increase the performance of the service provider value chain (Dehning, Richardson, & Zmud, 2007), and create new competitive advantages for maintenance providers by anticipating equipment failures, and diagnosing failures when they occur, isolating the problem and identifying spare parts needed for the repair before a maintenance technician is even dispatched (Blumberg, 2002: 108; 2004: 471–472). This therefore decreases the downtime of out-of-service medical devices. When hospitals purchase highly complex equipment and the OEM refuses to allow other maintenance organizations access to products such as online diagnostics programs, hospitals are locked into maintenance contracts with the OEM in order to gain access to such services, driving costs above what they would be in a competitive environment. In fact, this has generated significant controversy in the field of medical device maintenance, as some scholars have noted, "in some cases, it is almost impossible to service the equipment without this software, a situation that obviously has the potential to seriously hamper in-house or third-party service" (Temple-Bird et al., 2005c: 39). Yet while it is clear that the highly specific, necessary assets of online diagnostic tools create asymmetric power relationships that influence governance selection and financial performance (Blumberg, 2004: 471), there is an absence of theoretical and empirical research describing the influence on financial performance measured as maintenance service quality. Thus, we hypothesize that:

**Hypothesis 2.** Providing online service improves financial performance of maintenance transaction for both internal and external governance structures.

That online diagnostic tools improve the financial performance of any service provider should be obvious. For example, a survey conducted to over 100 maintenance service providers (i.e. externals governance structures) indicated that online diagnostic tool reduced the training time and eliminated the effort required to collect and analyze repair and maintainability data (Blumberg, 2004: 471). However, full quantifiable measurement of online diagnostic tools cost benefits has yet to be demonstrated in a broad sense. For example, just as a restriction of access to these services by the OEM creates asymmetric power relationships that allow the OEM to drive up prices, we believe these same asymmetric power relationships should generate lower efficiency pressures for OEM maintenance service providers, which should increase waiting times for servicing equipment above what they would be in a competitive environment. At the same time, when hospitals have access to online diagnostic tools, they are able to make use of their natural advantages, such as site and organizational specificity, that allow them to service equipment faster than other service providers. As a result, while online diagnostic services should have positive implications for service quality and financial performance regardless of the governance form selected, the positive influence should be stronger on hybrid governance forms that allow hospitals to lease diagnostic software, while internalizing the actual equipment maintenance tasks. Thus, we hypothesize that:

**Hypothesis 2a.** Providing online service has a stronger positive effect on the financial performance of the maintenance transactions of internal governance structures than external governance.

We believe that the maintenance performance associated with governance structure selection not only depends on assets specificity, but also the type of healthcare institution in which maintenance service is provided. Ample theoretical and empirical work has been conducted in this area previously, and several scholars have dealt with the question of governance selection for medical device maintenance and other medical services by examining performance according to whether healthcare institutions are private (either for-profit or non-profit) or public, or between for-profit or non-profit private hospitals (Ashton, 1988; Balakrishnan, Eldenburg, Krishnan, & Soderstrom, 2010; Coles & Hesterly, 1998a; Coles & Hesterly, 1998b; Dranove & White, 1994; Mark, 2009; Pauly, 1987; Zinn, Mor, Intrator, Feng, & Davis, 2003). However, empirical results have been mixed and contradictory, creating an unresolved, polemic debate. A primary point of conflict in the literature arises between scholars who find that TCT has effects on the vertical integration decisions and performance of healthcare services primarily in the private sector Coles and Hesterly (1998a) and Coles and Hesterly (1998b), and others who have found that that the core constructs of TCT have effects on both private and public, and for-profit and non-profit healthcare services. For example, Ashton (1988) studied the effects of assets specificity, uncertainty and frequency of transactions on contracting costs in four types of healthcare services (e.g. acute mental health services, rest homes, primary healthcare clinics, and surgical services), finding evidence for the effects on contracting costs for both private and public healthcare facilities. Additionally, Zinn et al. (2003) found that independently operating healthcare facilities showed less propensity for the vertical integration of services than those that operated as part of a healthcare network or chain.

Yet in their examination of vertical integration decisions in public and private hospitals, Coles and Hesterly (1998a, 1998b), found starkly different results. Individually testing the integration of specific medical services (e.g. Laboratory, Respiratory Therapy, Radiology, Maintenance, Housekeeping, etc.), they found that increases in the level of uncertainty in transactions lead health care institutions to integrate services at lower levels of assets specificity. However, their results were driven mainly by private hospitals, while integration decisions in public healthcare institutions were apparently uninfluenced by TCT variables. In an empirical comparison of for-profit and non-profit hospitals, Mark (2009) studied the effects of assets specificity, operationalized as the level of specialization of human skills, on governance selection decisions for information systems operations in 4608 non-profit, for-profit and catholic hospitals in the United States. Authors found a negative relationship between assets specificity and the number of functions the hospital-based health care systems outsourced. These results suggest that hospitals and healthcare systems may not be taking into account other factors, such as costs, which should be an important factor when facing outsourcing decisions. In another approach, Balakrishnan et al. (2010), found that government and non-profit hospitals are less likely than for-profit hospitals to engage in outsourcing. Finally, Wholey, Padman, Hamer, and Schwartz (2001) studied the effects of assets specify on outsourcing for development and operation activities among health care organizations, controlling for specific fixed effects such as organization type, finding that for-profit healthcare institution were more likely to outsource, while non-profit and public healthcare institutions were less likely to outsource these activities.

Multiple arguments explain these contradictory results. For example, Richards (1984) has argued that public entities are less sensitive to efficiency pressures than their private sector peers because their missions are different. The main goal of public hospitals is to provide service to vulnerable populations unable to pay for those services,[10] whereas the objective of private hospitals is to increase shareholder value, according to basic social and legal regulations driven by ethical behavior (Gray, 1986). Therefore, private hospitals are driven mainly by market forces and experience fewer constraints in the decision making processes; public hospitals may face pressure to spend all funds available to them in an effort to acquire more funding for the following fiscal year, or face special conditions as to which external providers they may contract, which can decrease their efficiency. Thus, faced with different constraints, managers of public healthcare institutions may systematically choose a certain governance structure, even if greater transaction costs are involved (Balakrishnan et al., 2010; Coles & Hesterly, 1998a).

These contradictions may rise up because the idiosyncratic nature of the conditions in the healthcare industry suggests that some environmental variables usually used in analyzing other organizations are not applicable in analyzing healthcare institutions, indicating that more specific models should be tested (Goldstein, Ward, Leong, & Butler, 2002). Given the facts that first, results obtained regarding the effects of the core constructs of TCT on the healthcare institution type are still contradictory; and second, that the empirical evidence on the performance of maintenance service governance structure is scant, we believe that the maintenance performance of both external and internal governance deserves to be studied according to hospital type. This holds especially true because of the managerial implications these findings may have for future outsourcing decisions. Based on this reasoning, we hypothesize that:

**Hypothesis 3.** Irrespective of the governance structure chosen, maintenance transactions performed in private healthcare institutions will show higher financial performance than in public healthcare institutions.

**Hypothesis 3a.** External governance structures will show higher financial performance in maintenance transactions for private healthcare institutions than for public healthcare institutions.

**Hypothesis 3b.** For public healthcare institutions, the financial performance of maintenance transactions of internal governance structures will be higher than external governance.

The relationships between independent variables and maintenance financial performance, according to service provider type are summarized in the conceptual model in Fig. 1. We tested all our hypotheses by building a multilineal regression model.

## 4. Research methods

### 4.1. Data sample

We gathered primary data on maintenance transactions from hospitals under study, resulting in a total sample of 1403 observations, each representing a unique maintenance transaction. We determined this sample size was sufficient, using as parameters an effect size of 0.2 and a statistical power of 0.8 (at $< 0.05$) (see (Portney & Watkins, 2000: 852) for more details).[11] Due to the scarcity of previous empirical and longitudinal studies on maintenance performance, we chose a low effect size in order to be conservative. The maintenance transactions were completed by 62 external maintenance service organizations and two in-house clinical engineering departments on a total sample of 764 medical devices located in several Colombian hospitals (11 private and 11 public). By measuring the Service cost – acquisition cost ratio (COSR) for each maintenance transaction according to governance structure, we were able to measure the financial performance of internal and external governance structures (see data collection procedure and bias control section for more details).

We selected the equipment in our data sample from nine pilot areas in the hospitals under study,[12] including: Diagnostic Images, Surgical Unit, Intensive Care Unit, Neonatal Care, Emergency, Intermediate Care Unit, Immunology Laboratory, Clinical Laboratory, and Microbiology. The technical complexity, equipment types, and equipment acquisition costs involved in these areas makes them the most likely to have maintenance services contracted to an external provider. In our selection of hospitals to be included in the study, we first looked at a large sample hospitals, and narrowed down the number of potential candidates for inclusion, taking special care to select hospitals that met similar criteria: accredited by the quality assurance system of the Republic of Colombia; comparable in terms of the number of licensed beds, number and types of medical devices, number and types of medical services, and level of care; possessing in-house clinical engineering departments that perform both preventive and corrective maintenance tasks; hospitals should be selected such that 90% of the maintenance service providers contracted render services to all hospitals included in the study; and finally, the hospitals should have sufficient information systems processes to gather, monitor and process all the equipment history and the maintenance transactions in our study. We acquired this information from the Bogotá section of the Colombian Ministry of

[10] For the years 1979–1982, between 11% and 12% of public hospital revenues were spent on uncompensated care; while the amount in private non-profit and for-profit private hospitals was 4% and 3%, respectively (Richards, 1984).

[11] We used a combination of the Portney and Watkins (2000: 852) table C.8 for the determination of lambda values (at $\alpha < 0.05$, with 8 predictors, i.e. $k = 8$) for regression analysis and the formula $n = \lambda * (1 - R * R)/R * R$ to estimate our required sample size required. where $n$ is the required sample size, $\lambda$ is a parameter depending of residuals degree of freedom (df residual). For our case the determined value of $\lambda$ is 17.4 at df residual = 120, and $R$ is the effect size. That for the case of our study design is $R = 0.2$. Therefore according to the formula our required sample size is $69.6 \approx 70$ observations or maintenance transactions.

[12] We got 1403 observations, each representing a unique maintenance transaction in from 72 different maintenance service providers performed in 22 hospitals.

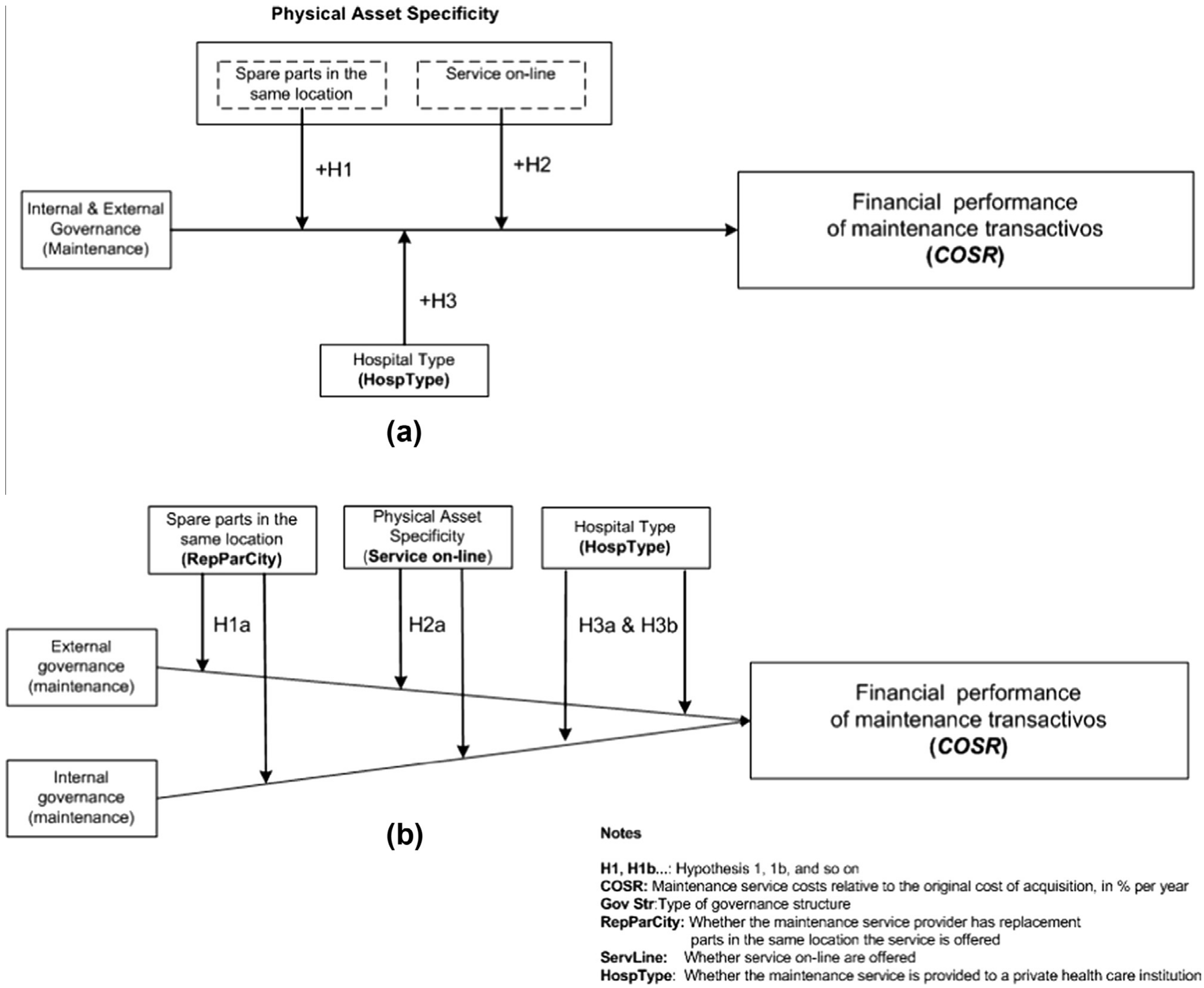


**Fig. 1.** Conceptual model of how assets specificity influences financial performance on maintenance transactions: (a) conceptual model to test Hypothesis 1, 2, and 3; and (b) conceptual model to test Hypothesis 1a, 2a, 3a and 3b.

Health, which left us with only five hospital candidates that meet the conditions mentioned above.

### 4.2. Data collection procedure and bias control

The 1403 maintenance transactions in our sample were characterized according to governance structure, the basic data of the equipment being serviced, the type of healthcare institution, and financial performance (i.e. COSR, in%/year). In doing so, we first conducted a study characterizing the hospitals' inventories from the pilot areas mentioned above to identify the equipment features, such as obsolescence level (Obsolesc), complexity level (TComplex), the equipment acquisition cost, the acquisition date, the equipment age, and the maintenance service provider in charge of the equipment, either internal or external. Once we identified the equipment maintenance service provider and the governance structure type (GovStr), we designed a survey conducted via face-to-face interviews with maintenance service firm managers and managers of hospital clinical engineering departments. The survey recorded only the main features and services offered by both internal and external maintenance providers. Among the most important data surveyed were company name; contract service start date; contract service end date; experience and qualifications of the company's human resources, in years and degrees obtained (TechTLevel); contract duration, in years; whether the contract is a guarantee contract; whether the contract includes replacements parts; total quantity of equipment included in the contract; number of annual visits stipulated in the contract; total number of the company's engineers and technicians; number of engineers and technicians working on the contract; distance of the service provider from the hospital, in kilometers; experience of the company in the industry, in years (CompExp); whether on-line maintenance services are offered (ServLine); whether replacement stocks exist in the same locality in which maintenance service is provided (RepParCity); equipment types involved in the maintenance contract service and whether training is provided to users and operators. Finally, as mentioned above, we collected primary data on hospital equipment maintenance incidents[13] and the performance of maintenance service organizations (both internal and external) over a twenty-month period by means of a monitoring procedure. The monitoring procedure is presented in Fig. 2.

[13] Information on maintenance incidents was recorded through documents called work orders, using a well-established work order standard form recommended by the Advanced Association for Medical Instrumentation (AAMI, 2002).

In order to avoid bias, all users were trained at the beginning of the study, and each new user (such as a new clinician hired by the hospital during the time of data collection) was trained as part of the induction period for the job. Additionally, each maintenance service provider was monitored through a monthly phone survey in order to identify any changes in their characteristics related to the independent variables in the study. To avoid any bias related to testing, maintenance service providers knew they were participating in a study, but were unaware that it was specifically their TAT performance that was being measured. During the ten month data collection phase of the study, no maintenance service provider showed any changes in the firm characteristics related to the independent variables measured in the original service provider survey, and no device was withdrawn from the equipment inventory. Finally, the hospitals contracted no new maintenance service providers, nor did they acquire any new devices during the model building and data collection period. As a result, there was no need to deal with attrition or history bias.

### 4.3. Selection and operationalization of variables

Table 1 lists the variables, variable type (e.g. independent, dependent, or control), description, and codification. The variables in Table 1 were grouped according to the vast theoretical grounding and empirical studies that already exist on both TCT and maintenance in the medical device field (Roberts and Han, 2004; Cohen, 2010; Coles & Hesterly, 1998a, 1998b; Cruz & Denis, 2006; Cruz, Perilla et al., 2010; Dranove & White, 1994; ECRI, 1989; Ho, Xu, & Dey, 2010; Miguel et al., 2002, 2007; Shelanski & Klein, 1995). We will now proceed to explain how and why all our measures and control variables were included in our model.

#### 4.3.1. Dependent variable

Maintenance performance has several dimensions (e.g. response time, service time, financial, etc., Cohen, 2010). However, for this study we used a measure of cost inclusive performance, the Service cost – acquisition cost ratio (COSR) as dependent variable. According to TCT, one of the most important determinants of governance selection is cost (Williamson, 1991). Therefore, in this paper we decided to include the maintenance service costs relative to the original cost of acquisition, in% per year, as dependent variable as a measure of financial performance associated with maintenance tasks (Cohen, 2010) (e.g. labor and specific spare parts and ancillary devices) in our evaluation of governance financial performance.

#### 4.3.2. Selection and operationalization of independent variables

Recall that assets specificity refers to the degree of investment required, or that is uniquely dedicated to support a maintenance transaction. We selected whether the maintenance service provider has replacement parts in the same location the service is offered (RepParCity), and whether online services are offered (ServLine) as independent variables. With the current debate on whether healthcare institution type affects performance and governance structure choice, the third variable we used was whether the maintenance service is provided to a private or public health care institution (HospType) (see Table 1 for more details).

*4.3.2.1. Repair parts in the city (RepParCity).* We included this independent variable to quantify how the availability of highly specific spare parts affects maintenance performance. If the maintenance transaction was performed by means of specialized spare parts with stocks located in the same city, it was coded as ‘1’, while transactions performed using specific spare parts from distant stocks were coded as ‘0’.

*4.3.2.2. Service online (ServLine).* As providing online service is a critical element to perform many maintenance tasks, mainly in high complexity technology (e.g. resonance magnetic imaging, or computerized tomography scanners). If the maintenance transaction was performed by means of specialized service online, we coded it as ‘1’, otherwise it was coded as ‘0’.

*4.3.2.3. Hospital type (HospType).* We included hospital type to study the effects of institution type on the maintenance performance of the governance structure. In this research, HospType was considered as a dummy variable, with public hospitals coded as ‘0’, and private hospitals coded as ‘1’.

#### 4.3.3. Selection and operationalization of control variables

In this paper we controlled for variables that were not of direct interest for testing our hypotheses, but still should have an impact on the dependent variable.

*4.3.3.1. Technological complexity (Complex).* Maintenance transaction tasks have been found to take more time as technological complexity of medical devices increases (Blumberg, 2004; Cheng, 2004). Thus, we expect higher COSR values for more complex equipment. Therefore, we included and controlled for equipment technological complexity in our statistical model. We used the well-accepted, established, and validated technological complexity scale proposed by (Temple-Bird et al., 2005c: 109), which has proven effective in a diverse array of countries (including underdeveloped countries). The scale classifies technology into three categories, including high, medium and low complexity (see Table 2 for more details), taking into account the level of technological sophistication in terms of hardware and software design and requirements, complexity of maintenance tasks, and level of training required to operate and maintain the devices. We coded high technological complexity as “1” and low technological complexity as “0” (we did not have any medium-level complexity equipment in our data sample, (see Table 1 for more details).

*4.3.3.2. Technological Obsolescence (Obsolec).* In this study, we used technological obsolescence[14] as a control variable to determine whether to select either a frailty or nested case-control proportional hazards model, and as a control variable to avoid any confounding bias. One critical assumption of the proportional hazards frailty model is that covariables do not change with time. This critical assumption does not hold in the case of medical equipment, which is more likely to breakdown as it ages. Thus, COSR may be higher than normal for older equipment, erroneously identifying a maintenance service provider as having lower performance. In this study, we measured technological obsolescence using the ratio of equipment exploitation time over the useful life of the device, or ET/UL. The exploitation time, in years, was determined by subtracting the date the study began from the date on which the equipment entered the hospital inventory. The data on the useful life of the equipment was taken from the maintenance service manual provided from the original equipment manufacturer. In cases where the information was not available from the manufacturer’s manual, the data was gathered from the estimated useful life list published by (AAMI, 2002). If the ET/UL ratio is lower than one (ET/UL < 1), the equipment is not obsolete, while if the ratio is greater than one (ET/UL > 1) the equipment is obsolete, because it has passed what the original equipment manufacturer considers to be its useful life. We coded technological obsolescence as “0” if the value of the ET/UL ratio was lower than one, while obsolete equipment with ET/UL ratios

[14] According to the logic of TCT, technological obsolescence has been used as a measure of environmental uncertainty (Coles & Hesterly, 1998a, 1998b).

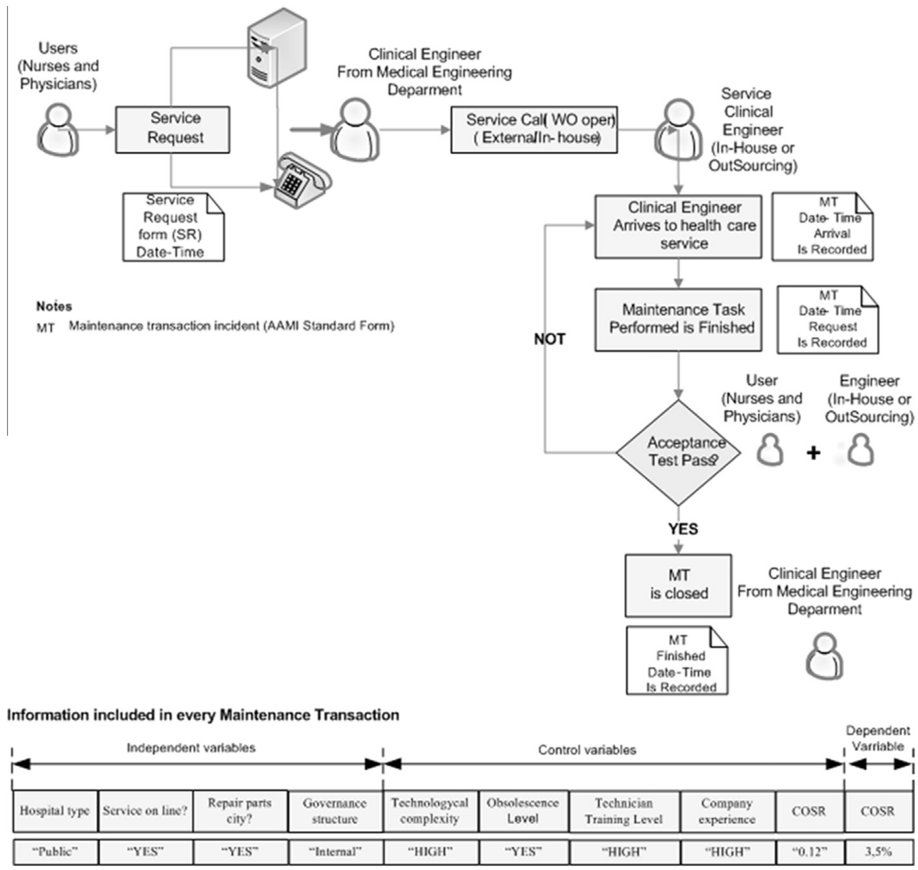


**Fig. 2.** Monitoring procedure of maintenance transactions.

**Table 1**
Operationalization of Variables.

| Variable name | Variable type | Variable description | Variable values |
|---|---|---|---|
| COSR | Dependent | Maintenance service costs relative to the original cost of acquisition. in%/year | $1-\infty$ |
| RepParCity | Independent | Whether the maintenance service provider has replacement parts in the same location the service is offered | YES = 1<br>NOT = 0 |
| ServLine | Independent | Whether online services are offered | YES = 1<br>NOT = 0 |
| HospType | Independent | Whether the maintenance service is provided to a private health care institution | PUBLIC = 0<br>PRIVATE = 1 |
| TComplex | Control | Technical complexity of equipment | LOW = 0<br>HIGH = 1 |
| Obsolec | Control | Equipment level of obsolescence | NOT = 0<br>YES = 1 |
| CompExp | Control | Experience of the company in the industry. in years | LOW = 0 (0–10 years in the business)<br>HIGH = 1 (>10 years in the business) |
| TechTLevel | Control | Technician training level | LOW = 0 Low complexity equipment. > 2 years of experience personnel. maintenance tasks performed by artisans<br>HIGH = 1 High complexity equipment. > 10 years of experience personnel. maintenance tasks performed by specialist and specialized engineers |
| GovStr | Independent | Type of governance structure involved in the maintenance tasks | INTERNAL: 0<br>EXTERNAL: 1 |

of greater than one were coded as "1" (see Table 1 for more details). This transformation from a ratio to binary scale for this variable has proven feasible in many applications to measure the obsolescence of medical devices (Cruz & Denis, 2006; Cruz, Denis, Villar, & Gonzalez, 2002).

*4.3.3.3. Company experience (CompExp).* We included the number of years of business experience of each company in our model because more experienced companies should show higher maintenance performance. These companies are better able to efficiently allocate resources, and to have local stocks of critical,

**Table 2**
Correlation matrix for the covariables.

| Variable code | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. COSR | 1.000 | | | | | | | | |
| 2. RepParCity | −0.116[1] | 1.000 | | | | | | | |
| 3. ServLine | −0.111[1] | −0.032 | 1.000 | | | | | | |
| 4. HospType | −0.164[1] | +0.240[1] | −0.095[1] | 1.000 | | | | | |
| 5. TComplex | +0.170[1] | −0.193[1] | −0.515[1] | −0.09[1] | 1.000 | | | | |
| 6. Obsolesc | −0.014 | +0.077[1] | −0.014 | −0.12[1] | −0.172[1] | 1.00 | | | |
| 7. CompExp | +0.209[1] | −0.05 | −0.084[1] | +0.05[1] | −0.05[2] | −0.08[1] | 1.00 | | |
| 8. TechTLevel | −0.184[1] | −0.178[1] | −0.038 | +0.07[1] | −0.089 | −0.02 | +0.37[1] | 1.00 | |
| 9. GrvStr | −0.322[1] | −0.218[1] | −0.165[1] | −0.647[1] | −0.305[1] | +0.07[1] | −0.06[1] | +0.75[1] | 1.00 |

*Notes:* [3] $p < 0.1$ Significance level (2-tailed).
[1] $p < 0.01$ Significance level (2-tailed).
[2] $p < 0.05$ Significance level (2-tailed).

highly specific spare parts. Any company with more than 10 years (high experience) in the industry was coded as "1", and companies with fewer than 10 years of industry experience (low experience) we coded as "0" (see Table 1 for more details).

*4.3.3.4. Technician skill and training level (TechTLevel).* The more complex the equipment, the more significant and important the technical skills needed to perform the maintenance tasks (Temple-Bird et al., 2005c: 175). We expect the technician training level to improve maintenance performance. Thus, we controlled for technician training involved in the maintenance transactions. We used the well-accepted, established, and validated maintenance skills scale proposed by Temple-Bird et al. (2005b: 42), which has proven effective in a diverse array of countries (including underdeveloped countries). The scale classifies the skill level needed to perform maintenance tasks as a function of technology type, the qualifications of the personnel, and the type of maintenance task to be performed in the transaction (Table 1 for more details). We coded high skill levels as "1", and low skills levels as "0" (we did not have medium skill level technicians in our data sample).

*4.3.3.5. Governance Structure (GovStr).* Finally, we controlled for differences in the governance structure for each maintenance transaction. We coded internal governance structures as '0', and external structures as '1'.

### *4.4. Statistical procedure and model building method*

Once the information was completely entered into the computerized equipment management system, all service provider names were coded. The list of names and corresponding codes was stored in a sealed envelope to ensure the identity of each provider was hidden. Next, we conducted a descriptive statistical analysis for all variables. After conducting both Kolmogorov–Smirnov (0.9965, $p < 0.457$) and Shapiro–Wilk (0.9842, $p < 0.561$) tests for the COSR variable, data showed a normal distribution, therefore; we selected a multilinear regression as statistical model to test our hypothesis. We built our model using the method proposed by (Kleinbaum and Mitchel: 165–299; Hekman et al., 2010). We centered all variables involved in the interaction terms to minimize multicollinearity effects between the interaction terms and their individual components of our model (Aiken & West, 1991; Hekman et al., 2010). Then we performed both multicolinearity diagnostic and autocorrelations test[15] of our data. Our data showed neither collinearity nor autocorrelation problems (see results section for more details). Next, we used a forward regression method[16] to build our multilinear regression model. In doing so, we first entered all individual independent variables (i.e. RepParCity, ServLine, HospType) in Model I, but excluding control and interaction variables. Next, we performed the confounders assessment followed by consideration for precision[17] by entering all the control variables without the interactions, which is presented in Model II (i.e. TComplex, Obsolec, CompExp, TechTLevel, GovStr). We assessed the confounders' impact on the models by determining whether the estimated $\beta$ coefficients meaningfully changed when selected confounders'variables were entered or deleted from the model[18]. Finally, in Model III we entered all the interactions involving governance maintenance structure[19]. (i.e. (RepParCity) ∗ (Gov Str), (ServLine) ∗ (Gov Str), (HospType) ∗ (Gov Str), (TComplex) ∗ (Gov Str), (Obsolesc) ∗ (Gov Str), (CompExp) ∗ (Gov Str), (TechTLevel) ∗ (Gov Str) see Tables 2 and 3 for more details). As a rule for any interaction term found statistically significant, we applied a hierarchy principle identifying lower components that must remain in the final model (i.e. if certain interaction component is to be retained in the model, then all the lower-order components of that interaction are to be retained). The model of primary interest, Model III, is thus specified as follows:

$$\begin{aligned} COSR = {} & \beta_1 * \mathrm{RepParCity} + \beta_2 * \mathrm{ServLine} + \beta_3 * \mathrm{HospType} + \beta_4 \\ & * \mathrm{TComplex} + \beta_5 * \mathrm{Obsolec} + \beta_6 * \mathrm{CompExp} + \beta_7 \\ & * \mathrm{TechTLevel} + \beta_8 * \mathrm{GovStr} + \beta_9 * (\mathrm{GovStr} * \mathrm{RepParCity}) \\ & + \beta_{10} * (\mathrm{GovStr} * \mathrm{ServLine}) + \beta_{11} * (\mathrm{GovStr} * \mathrm{HospType}) \\ & + \beta_{12} * (\mathrm{GovStr} * \mathrm{TComplex}) + \beta_{13} * (\mathrm{GovStr} * \mathrm{Obsolesc}) \\ & + \beta_{14} * (\mathrm{GovStr} * \mathrm{CompExp}) + \beta_{15} * (\mathrm{GovStr} * \mathrm{TechTLevel}) \end{aligned}$$

*Note 1:* see Table 1 for more details (variables definition and operationalization)

## 5. Results

Table 2 correlation coefficients between the dependent, independent, and control variables. In Table 3a, Models I, and II present the results of the tests of Hypotheses 1, 2, and 3, which posit that the presence of spare parts in the same city where serviced equipment is located has a positive impact on the financial performance

[15] COSR variable measures repeated maintenance transactions amongst the service providers, therefore autocorrelation might exist.

[16] We used hierarchical regression models. This method starts with a model containing all main effects (i.e. individual components) and proceed sequentially add statistically significant interactions terms (Sheskin, 2007:1735).

[17] Dropping variables is precision is gained by examining confidence intervals (CIs).

[18] As a rule we used a "change-of-estimate" rule of 5% or greater to retain a confounder in the model.

[19] We also assessed the confounding interactions by analyzing the precision gained using the confidence intervals (CIs) criteria (i.e. the lower the better, more precision).

**Table 3**
Regression analysis dependent variable: COSR indicator.

| Variable name | Model I $H_1$, $H_2$ and $H_3$ | | | Model II $H_1$, $H_2$ and $H_3$ | | | Model III H1a, H2a and H3a, H3b | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\beta$ | SE | Stat Sig | $\beta$ | SE | Stat Sig | $\beta$ | SE | Stat Sig |
| *(a) Coefficients* | | | | | | | | | |
| RepParCity | −0.350 | 0.135 | 0.010 | −0.410 | 0.135 | 0.010 | −0.380 | 0.112 | 0.000 |
| ServLine | −0.266 | 0.095 | 0.005 | −0.320 | 0.095 | 0.005 | −0.360 | 0.087 | 0.003 |
| HospType | −0.150 | 0.020 | 0.000 | −0.191 | 0.020 | 0.000 | −0.159 | 0.030 | 0.000 |
| TComplex | | | | +0.415 | 0.082 | 0.000 | +0.420 | 0.072 | 0.000 |
| Obsolesc | | | | −0.427 | 0.035 | 0.45 | −0.430 | 0.050 | 0.680 |
| CompExp | | | | +0.306 | 0.066 | 0.000 | +0.317 | 0.057 | 0.000 |
| TechTLevel | | | | −0.390 | 0.054 | 0.000 | −0.389 | 0.046 | 0.000 |
| GovStr | | | | −0.203 | 0.034 | 0.000 | −0.233 | 0.036 | 0.000 |
| *Interactions* | | | | | | | | | |
| (RepParCity) ∗ (Gov Str) | | | | | | | −0.100 | 0.049 | 0.042 |
| (ServLine) ∗ (Gov Str) | | | | | | | −0.220 | 0.046 | 0.000 |
| (HospType) ∗ (Gov Str) | | | | | | | +0.156 | 0.034 | 0.000 |
| (TComplex) ∗ (Gov Str) | | | | | | | +0.118 | 0.026 | 0.000 |
| (Obsolesc) ∗ (Gov Str) | | | | | | | −0.099 | 0.080 | 0.000 |
| (CompExp) ∗ (Gov Str) | | | | | | | −0.064 | 0.057 | 0.000 |
| (TechTLevel) ∗ (Gov Str) | | | | | | | −0.034 | 0.090 | 0.000 |
| Statistics overall model | ANOVA test: ($F = 11.256$, $p < 0.000$)<br>$R = 0.231$<br>$R^2 = 0.053$<br>Durbin–Watson test: $d = 2.01$ | | | ANOVA test: ($F = 15.532$, $p < 0.000$)<br>$R = 0.504$<br>$R^2 = 0.254$<br>$R^2 = 0.201$<br>Durbin–Watson test: $d = 1.998$ | | | ANOVA test: (F = 50.726, $p < 0.000$)<br>$R = 0.726$<br>$R^2 = 0.527$<br>$R^2 = 0.273$<br>Durbin–Watson test: $d = 2.05$ | | |

| Variable name | Collinearity statistics | |
|---|---|---|
| | Tolerance | VIF |
| *(b) collinearity statistics* | | |
| RepParCity | 0.793 | 1.261 |
| ServLine | 0.801 | 1.249 |
| HospType | 0.897 | 1.115 |
| TComplex | 0.642 | 1.558 |
| Obsolesc | 0.951 | 1.052 |
| CompExp | 0.638 | 1.568 |
| TechTLevel | 0.529 | 1.890 |
| GovStr | 0.809 | 1.235 |

| Dimension | Eigenvalue | Condition index | Variance proportions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| *(c) collinearity diagnostics* | | | | | | | | | | | |
| Constant | 7.71 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| RepParCity | 0.15 | 7.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.06 |
| HospType | 0.40 | 4.39 | 0.00 | 0.00 | 0.00 | 0.01 | 0.11 | 0.01 | 0.06 | 0.00 | 0.00 |
| ServLine | 0.48 | 4.01 | 0.00 | 0.00 | 0.04 | 0.05 | 0.00 | 0.59 | 0.00 | 0.15 | 0.01 |
| TComplex | 0.24 | 5.68 | 0.00 | 0.01 | 0.12 | 0.24 | 0.01 | 0.03 | 0.06 | 0.24 | 0.00 |
| Obsolesc | 0.32 | 4.94 | 0.00 | 0.04 | 0.07 | 0.03 | 0.00 | 0.35 | 0.05 | 0.19 | 0.05 |
| CompExp | 0.12 | 8.13 | 0.00 | 0.44 | 0.13 | 0.05 | 0.01 | 0.00 | 0.11 | 0.23 | 0.13 |
| TechTLevel | 0.21 | 6.12 | 0.00 | 0.15 | 0.26 | 0.16 | 0.93 | 0.03 | 0.01 | 0.00 | 0.00 |
| GovStr | 0.15 | 7.17 | 0.99 | 0.36 | 0.38 | 0.19 | 0.05 | 0.00 | 0.76 | 0.16 | 0.75 |

End notes.
n: 1043 maintenance transactions.
SE: Standard error.
$\beta$: Model coefficients.
Stat Sig: Statistical significance ($p$ value).
Since in this study our dependent variable was the Service cost – acquisition cost ratio, COSR, the interpretation should be made with caution. For example, the $\beta$ negative coefficient of RepParCity variable corresponds to a lower value of COSR when RepParCity changes from "NOT = 0" to "YES = 1" (i.e. lower COSR indicator = higher financial performance for maintenance transactions), which is a positive result.
*Notes:* VIF: variation inflation factor

of maintenance transactions of both internal and external governance structures. (i.e. $COSR_{RepParCity = YES} < COSR_{RepParCity = NOT}$, $\beta_{(RepParCity)} < 0$); providing online service improves the financial performance of maintenance transactions for both internal and external governance structures. (i.e. $COSR_{ServLine = YES} < COSR_{ServLine = NOT}$, $\beta_{(ServLine)} < 0$); and irrespective of the governance structure chosen, maintenance transactions performed in private healthcare institutions will show higher financial performance than in public healthcare institutions. (i.e. $COSR_{HospType = PRIVATE} < COSR_{HospType = PUBLIC}$, $\beta_{(HospType)} < 0$).

In Model II one can see that $\beta_{RepParCity}$ coefficient is below 0 (i.e. $\beta_{RepParCity} = -0.410$), indicating an inverse relationship between RepParCity and COSR variables. In other words, when RepParCity variable changes from RepParCity = NO = 0 to RepParCity = YES = 1, the COSR decreases, which means that financial performance of maintenance transactions increase, with a $p$ value < 0.05 we can assert that Hypothesis 1 is supported. Also, in Model II the $\beta_{ServLine}$ coefficient is below 0 (i.e. $\beta_{ServLine} = -0.320$), indicating an inverse relationship between ServLine and COSR variables. In other words, when ServLine variable changes in one unit from ServLine = NO = 0 to ServLine = YES = 1, the COSR decreases, which means that financial performance of maintenance transactions increase, with a $p$ value < 0.05 we can assert that Hypothesis 2 is supported.

Furthermore, in Model II the $\beta_{\text{HospType}}$ coefficient also is below 0 (i.e. $\beta_{\text{HospType}} = -0.191$), indicating an inverse relationship between HospType and COSR variables. In other words, when HospType variable changes in one unit, from HospType = PUBLIC = 1 to HospType = PRIVATE = 2, the COSR decreases, which means that financial performance of maintenance transactions increase in private hospitals irrespective of the maintenance governance structure used, with a $p$ value < 0.05 we can assert that Hypothesis 3 is supported. Notice how the $\beta_{\text{RepParCity}}$, $\beta_{\text{ServLine}}$, and $\beta_{\text{HospType}}$ coefficients in Model II were more negatives compared with Model I after the introduction of TComplex, Obsolesc, CompExp, and TechTLevel control variables, indicating that these variables, mainly TComplex, CompExp, and TechTLevel (Obsolesc, had a non-significant statistical value, $p < 0.45$) have effects on financial performance of maintenance transactions. We believe that Model II provided an excellent empirical support for Hypotheses 1, 2, and 3, since the correlation coefficient ($R$) and determination coefficient ($R^2$) were high, i.e. Model II correctly classified 25.0% of all observations. Also, as a set, our variables explained a significant amount of incremental variance in the dependent variable from Model I to Model II ($R^2 = 0.201$ (i.e. 20.1%), ANOVA test, $p < 0.0001$). Table 3a presents the results of this analysis.

In Table 3, Model III and Figs. 3a, b and 4 present the results of the tests of Hypotheses 1a, 2a, 3a, and 3b which posit that the presence of spare parts in the same city where serviced equipment is located has a stronger positive effect on the financial performance of maintenance transactions of external governance structures than internal governance; providing online service has a stronger positive effect on the financial performance of maintenance transactions of internal governance structures than external governance; the financial performance of external governance structures is higher in maintenance transactions conducted in private hospitals than in public hospitals; and finally, in public healthcare institutions the financial performance in maintenance transactions of internal governance structures will be higher than for external governance structures.

Table 3 shows that the coefficient for the interaction term (RepParCity) ∗ (GovStr) is significant and in the expected direction for financial performance of maintenance transactions. We also plotted the interaction term (RepParCity) ∗ (GovStr) and conducted a simple slope analysis (see Model III and Fig. 3a). COSR indicators for both internal and external) maintenance governance structures were negatively related to RepParCity variable when it changes from "NOT = 0" to "YES = 1"; however, as posited Hypotheses 1a we observed that simple slopes of the simple regression lines decreases from $-1.48$ to $-1.85$ when governance maintenance structure changes from "INTERNAL = 1" to "EXTERNAL = 2" as RepParCity increases from "NOT = 0" to "YES = 1", indicating that external governance structures has better financial maintenance performance than internal (i.e. $\text{COSR}_{(\text{RepParCity=YES})\,*\,(\text{GovStr = EXTERNAL})} < \text{COSR}_{(\text{RepParCity = YES})\,*\,(\text{GovStr = INTERNAL})}$, and $\beta = -0.100$, $p < 0.001$).

Table 3 also shows that coefficient for the interaction term (ServLine) ∗ (GovStr) is significant and in the expected direction for financial performance of maintenance transactions. We also plotted the interactions and conducted a simple slope analysis (see Model III and Fig. 3b). COSR indicators for both internal and external maintenance transactions governance structures were negatively related to ServLine variable when it changes from "NOT = 0" to "YES = 1"; however as posited Hypotheses 2a we observed that financial performance of maintenance transactions of internal governance structures has better financial performance than external. (i.e. $\text{COSR}_{(\text{ServLine = YES})\,*\,(\text{GovStr = EXTERNAL})} > \text{COSR}_{(\text{ServLine = YES})\,*\,(\text{GovStr = INTERNAL})}$, $\beta = -0.220$, $p < 0.001$). In other words, slopes of the simple regression lines decreases from $-1.24$ to $-1.46$ when governance maintenance structure changes from "INTERNAL = 1" to "EXTERNAL = 2" as ServLine increases from "NOT = 0" to "YES = 1".

Contrary what we hypothesized, Model III shows that the coefficient for the interaction term (HospType) ∗ (Gov Str) goes in opposite direction. This result can be corroborated by plotting the interaction term (HospType) ∗ (Gov Str) and conducting a simple slope analysis. Fig. 3c shows that when HospType variable changes from "PUBLIC = 0" to "PRIVATE = 1"; the maintenance transactions of internal governance structures have lower financial performance than external and vice versa, which means that we did not find support for Hypotheses 3a and 3b. We also believe that

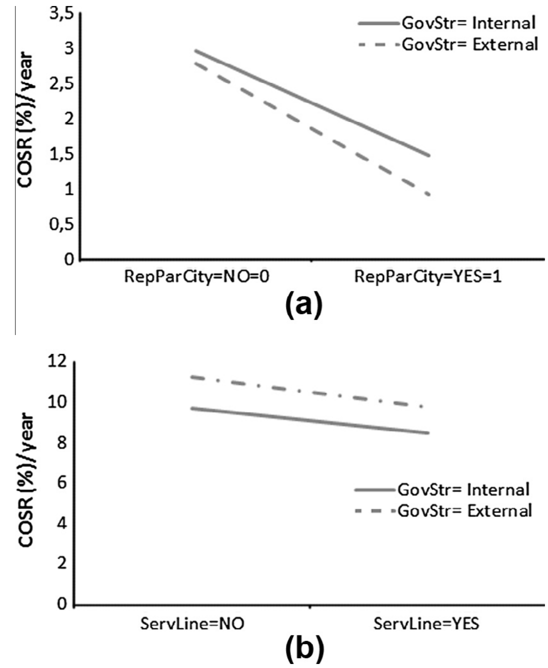


**Fig. 3.** Interactive effects of assets specificity and governance structure maintenance financial performance: (a) whether the maintenance service provider has replacement parts in the same location the service is offered and governance structure maintenance financial performance; (b) whether online services are offered and governance structure maintenance financial performance. *Note 1:* All significance levels of the simple slope were $p < 0.001$. *Note 2:* **GovStr**: Type of governance structure involved in the maintenance tasks; **ServLine:** Whether online services are offered; **RepParCity**: Whether the maintenance service provider has replacement parts in the same location the service is offered; and **COSR**: Maintenance service costs relative to the original cost of acquisition. in%/year.

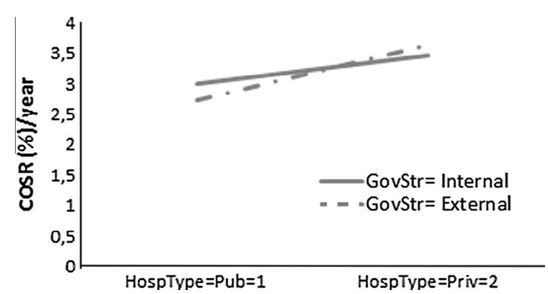


**Fig. 4.** Interactive effects of hospital type and governance structure maintenance financial performance. *Note 1:* All significance levels of the simple slope were $p < 0.001$. *Note 2:* **GovStr:** Type of governance structure involved in the maintenance tasks; **HospType**: Whether the maintenance service is provided to a private health care institution; and **COSR**: Maintenance service costs relative to the original cost of acquisition. in%/year.

Model III provided an excellent empirical model for Hypotheses 2a, 2a, 3a, and 3b, since the correlation coefficient (R) and determination coefficient ($R^2$) were high, correctly classifying 52.7% of all observations in Model III. Also, as a set, our variables explained a significant amount of incremental variance in the dependent variable from Model II to Model III ($R^2 = 0.273$ (i.e. 27.3%), ANOVA test, $p < 0.0001$). Table 3a presents the results of this analysis. Overall, we found statistically significant evidence to support five of our seven hypotheses posited.

Table 3b and c summarize the collineality analysis. Notice that all tolerance values computed for both the predictors and control variables are closer to the maximum possible value of 1, and that result is consistent with the absence of multicolinearity. Also, this conclusion is further reinforced by the fact that none of values computed for the condition indexes for both the predictors and control variables do not exceeds 15 units[20] (i.e. the largest value being 8.13). Therefore, we can conclude there is no evidence of multicolinearity. On the other hand, the statistics overall model row in Table 3a shows no significant values for Durbin–Watson tests[21] (i.e. d values of 1.850, 1.865 and 1.79 for Models I, II and III respectively). Therefore, we can conclude there is no evidence of autocorrelation of our data sample (i.e. there is no violation of the assumption of independence of residuals).

## 6. Discussion of theoretical impact and managerial implications

Our paper responds to the claim made by Geyskens et al. (2006, p 534), which asserted that "greater effort to understand the influence of governance choice on performance is needed". In response to that claim, we have tried to answer their research question "How does the [financial] performance of the firms that adopt a particular governance arrangement compare to that of firms that adopt alternatives to that arrangement?" (Geyskens et al., 2006, p.534). In doing so, our research attempted to measure the impact of assets specificity on the financial performance of outsourced and in-house medical device maintenance service providers, using the TCT lens. Our solutions to the difficulties of measuring financial performance of maintenance transactions and the considerably larger number of observed transactions ($n = 1403$ maintenance transactions) make our study significantly different from its predecessors.

Our results are consistent with other empirical research findings, in that scholars have found that assets specificity has an impact on the performance of the selected governance structure (Geyskens et al., 2006; Jin & Tian, 2012; Poppo & Zengert, 1998). For example, our results showed that the presence of high specific spare parts supplies in the city has a positive impact on the performance of both internal and external governance structures. However, regarding the effects of assets specificity differentiating by type of governance maintenance structure we have found mixed results. On one hand, we have found that when there is presence of idiosyncratic spare parts in the same city where serviced equipment is located, it has a stronger positive effect on financial performance of the maintenance transactions of external governance structures than internal governance. We have some explanations for these findings.

First, our findings support Crams (2002) theoretical assertion that outsourcing modality provides the ability to synchronize specific spare parts and components and locate hard-to-find parts for medical devices by using economies of scale, resulting in lower maintenance service costs. Second, internal maintenance governance structures often lack the ability to invest in these idiosyncratic assets due to the high costs of highly specific parts, and the additional cost of keeping parts in storage. As a consequence, according to Temple-Bird et al. (2005a), parts are ordered on an on-demand basis from an external supplier, such as the original equipment manufacturing, resulting in longer equipment downtime and higher maintenance costs. This last assertion supports the findings of Mirzahosseinian and Piplani (2011), in which the authors demonstrated that to improve the availability of the system under study with repairable specific spare parts, the supplier or service providers should work to improve the componentś reliability and efficiency of repair facilities, rather than the base stock level, which has minimal impact on system availability.

On the other hand, we found that online diagnostic tools had a stronger positive effect on the maintenance financial performance of internal governance than external governance. Our findings support the empirical findings made by other scholars, in which the adoption of information technology to perform some activities (e.g. maintenance tasks on complex equipment) inside of the firms has an improvement of performance as reflected in decreased operational costs and production costs (Dehning et al., 2007; Poppo & Zenger, 1998). Indeed, Blumberg (2004: 417) reported that the reduction in the total elapsed time for repair in complex calls results in costs reduction. Complex calls are typically about 20% of the total number of calls carried out by service organizations in the medical maintenance service. We have found some explanations of why this could happen. First, if the original equipment manufacturer does not have a formalized policy of supporting and updating maintenance diagnostic software with other maintenance companies (i.e. third parties maintenance organizations), they may view these other companies as competitors to their own equipment maintenance business. As a result they may delay or block the sale, support, and updating of specific supporting and updating maintenance diagnostic software. This in turn makes the third party organizations have to incur additional transactional costs to provide their maintenance service. Therefore, the vast majority of contracts with external service providers that includes online diagnostic services are between healthcare institutions and the original equipment manufacturer.

Second, since the original equipment manufacturers frequently refuse other service providers access to online diagnostic tools, these manufacturers face less competition, and as a result they may face less performance pressure. In addition, the original equipment manufacturers frequently maintains a monopoly over such tools in order to retain market power for its own equipment maintenance business; therefore, it is often nearly impossible for hospitals to gain access to online diagnostics while using internal governance for maintenance tasks. Our findings however, showed that in the cases where an in-house clinical engineering department had access to online diagnostic tools, internal governance financially performed better than external structures.

These mixed findings have some managerial implications. First, hospitals managers instead of eliminating their in-house service staff clinical engineering should think the way to carried out hybrids relationships among either original equipment manufacturers or third party organizations. This last assertion is in

[20] The presence of a condition index above 30 suggests serious multicollinearity, while a condition index between 15 and 30 indicates the possibility of multicollinearity. If two or more variables have a variance proportions of 0.50 or greater on a component with high condition index, there is a multicollinearity problem with respect to those variables (Sheskin, 2007:1465).

[21] More specifically employing Table A27 Critical values for the Durbin–Watson test statistic on (Sheskin, 2007: 1704) and http://www.standford.edu/~client/bench/dw05d.htm, it can be determined that for $n = 1043$, and $k = 8$ (i.e. the three main independent variables or predictors RepParCity, ServLine, HospType and control variables TComplex, Obsolesc, CompExp, and TechTLevel), the du value at alpha 0.05 is 1.90. Therefore, in order to conclude that there is no autocorrelation (i.e. residuals are not correlated, independence of residuals) we used the condition $1.90 < d < 4\text{-du}$. Since the computed d values in all models is greater than 1.91 but less than 2.10; therefore, we can conclude there is no evidence of the violation of the assumption of independence of residuals.

the vein of De Vivo et al. (2004) and Fallah-Finia, Triantisb, Garzac, and Seaver (2012) who pointed out that there is a strong belief that the most effective and economical way to maintain medical equipment is through the development of solid partnerships between external services providers and in-house service. Surprisingly, our suggestion goes against one of the most common assumptions in the medical device maintenance field where (Blumberg, 2004, p 144) found that clinical engineers ''believed that managed care had caused and that it would cause many hospitals to eliminate their in-house service staffs''. Our empirical results showed that the belief of externalizing maintenance services improves service quality and cost saving is not always true. Second, we suggest that in-house governance maintenance structures should create written contract safeguards (i.e. contract clauses) with original equipment manufacturers where the in-house structure is allowed to use the online diagnostic tools.

Furthermore, our results lend support for our Hypothesis 3, that hospital type influences the performance of the selected governance structure in maintenance transactions. However, our findings showed opposite directions what we hypothesized. Namely, we found contrary to our Hypothesis 3a and 3b that (1) for transactions conducted under external governance structures, the maintenance financial performance is lower in private hospitals than in public hospitals, and (2) internal governance structures show a better maintenance financial performance over external governance structures for private hospitals.

There may be various explanations for these results. First, our finding that internal transaction of in-house maintenance services have lower performance levels in public healthcare institutions compared to private can be explained by the fact that public healthcare institutions are subject to less severe efficiency pressures because they receive government subsidies that allow them to operate even when they fail to be profitable. Therefore, they may have different incentives (i.e. political) than private organizations operating in the same market (Coles & Hesterly, 1998a). In other words, it seems that effective adaptation and the elimination of waste in maintenance transactions (i.e. first-order economizing (Williamson, 1991)) in public healthcare institutions has been neglected, which in turn provoke lower maintenance financial performance levels in maintenance transactions in those type of healthcare institutions.

Second, our finding that internal maintenance transaction of in-house maintenance service has higher financial performance levels in private healthcare institutions can be explained by the fact that it seems that clinical engineering in private healthcare institutions perhaps isunderstanding the needs to realign their scope of services. In Grimes' (2003) seminal paper, stated that clinical engineering departments are arriving at a strategic inflection point.[22] For example, outsourcing maintenance model is threatening (i.e. are more cost-effective) the clinical engineering departments existence in health care institutions; and therefore, they are taking steps toward making a more effective economical adaptation in such institutions in order to obtain high-financial performance (Grimes, 2003), and not to be substituted by external providers.

## 7. Limitations and opportunities for future research

We believe that our findings provide strong, consistent support for our theoretical predictions. However, like all research, the results presented in this paper have some limitations. In the context of medical device maintenance outsourcing, we see five specific areas for future research. First, new variables that affect the performance of the maintenance service providers should be included in future studies. For example, the type of maintenance tasks (i.e. corrective versus preventive), the type and features of contractual relationships (i.e. contract duration, in years; whether the contract is a guarantee contract; the total quantity of equipment included in the contract; and whether the contract includes replacements parts), and the capacity of the firm to deliver the service, dependent on firm and human resources features (i.e. number of engineers and technicians working on the contract, and the quantity of contracts managed by the company) are all other variables that could be included in future studies. Second, future research should consider maintenance performance in transactions of other types of governance structures, such as Market (Classical Contracting), Trilateral Governance (Neoclassical Contracting), Bilateral or Unified Governance Structures (Williamson, 1979). Third, future research might focus on which capabilities and characteristics of medical device maintenance service providers affect the vertical integration or ''make or buy'' decisions made by managers of healthcare institutions. More specifically, according to TCT, how do asset specificity, uncertainty, and transaction frequency affect the decision-making processes of healthcare managers deciding whether or not to outsource a maintenance service, and which external provider to choose? Fourth, and most important, more research is needed to examine how the performance of maintenance service providers affects the quality or performance of medical service, in terms of input quality (staffing or equipment), process quality (length of stay of patients, numbers of tests and procedures performed), and output quality (mortality or morbidity of patients) (Dranove & White, 1994). Finally, we believe that we should include a composite effect of maintenance performance as a dependent variable, which takes into account both the COSR and the turnaround times of medical devices. We think this new composite indicator is more realistic and fits better to the healthcare environment, though economizing costs and financial performance are clearly important in healthcare, service quality may be a better indicator of performance in an industry in which human lives are very literally dependent upon the quality of services customers receive, and where the existence of publicly funded hospitals takes some validity out of measuring performance in terms of firm survival. In such contexts, it will be more useful to operationalize performance as a composite effects of both service quality (i.e. turnaround time) and financial performance of maintenance transactions (i.e. COSR).

One key to the success of our model is how we have operationalized ''asset specificity'' to generate the variables in our model. It is therefore natural to ask to what extent our model can be extended to other sectors. Clearly, each industry has its own particularities and must identify the variables that measure asset specificity in its own special context. It may be the case that a variable such as the availability of spare parts serves as an appropriate variable in other industries, yet in an industry such as software troubleshooting where available technicians are more important than spare parts, this variable might be irrelevant and asset specificity should be defined differently. Similarly, the special assets of a firm giving it a competitive advantage, here defined as the online diagnostic services, might work in other industries, or could be defined very differently. Still, what we believe does make our model highly generalizable to other industries is our inclusion of interaction variables. Researchers from other sectors must decide for themselves which variables define asset specificity for their industries; once these variables have been defined, however, creating interaction variables with the governance structure selected for the transaction will be key for measuring performance and identifying the best form of governance for carrying out maintenance services, given the specific context of the services to be performed.

[22] Is a term coined by Andrew Grove, Intel's chairman, which describes the time in which extreme forces forever alter the landscape on an industry.

Finally, while at first glance this may appear a highly specific field, we believe our research may have useful applications for other industries (e.g. automotive, aerospace, manufacturing, software development, etc.) because the multi-period machine maintenance problem with delegated control is a widespread problem (Plambeck & Zenios, 2000), making our research highly generalizable.

This means our research may be imitable for other industries in which equipment maintenance is a key issue. The problem of the multi-period machine maintenance problem with delegated control can be described by considering a critical piece of equipment, which can be in one of two possible states: functioning or non-functioning. Equipment only serves its purpose for the owner in an operational state. The owner delegates repair and maintenance schedule responsibilities to a third party, such as the original equipment manufacturer, or an independent service organization (i.e. outsource the maintenance service). The third party repairs the equipment when it is in a non-functioning state. While the equipment is in a functioning state, the third party conducts scheduled maintenance tasks, known as preventative maintenance. While the owner may not be able to efficiently monitor or precisely measure the outcomes of the third party's efforts, maintenance performance can be evaluated by observing the state of the equipment. The inability to effectively evaluate an outsourced service provider's performance causes what is known as the bounded rationality problem, in turn provoking the potential for opportunistic behaviour from the outsourced service provider. Consequently, bounded rationality and the threat of opportunism create exchange hazards for both the equipment owner and service provider. Thus, the owner faces two fundamental problems: (1) how to choose the appropriate degree of integration to obtain optimal performance levels for maintenance services (i.e. "*make or buy*" decision paradigm), and (2) how to measure the performance level of maintenance service providers, in order to make decisions regarding the optimal degree of integration. Our research provides both insights and empirical findings on how to tackle these two fundamental problems in the maintenance of medical devices; this is the main practical implications of our research.

## 8. Conclusions

This paper has attempted to use a TCT lens to identify the main determinants of medical device maintenance performance for both internal and external governance structures. Namely, we have quantified how assets specificity affects maintenance service provider financial performance, depending on the type of hospital. We have empirically supported our core theoretical argument that the maintenance financial performance of governance structures (e.g. internal or external) is influenced by transaction features (assets specificity), which create a scenario in which firms face a decision to accept higher transaction costs and provide quality service, or shirk these costs by providing lower quality service. The high values of the correlation and determination coefficients (i.e. $R$ and $R^2$), and the robustness of the $\beta$ coefficients with statistically significant values ($p < 0.01$ or $p < 0.05$) across all models give us enough statistical evidence to assert that we achieved the aim of our research. Finally, as maintenance outsourcing is a common problem, this research has the potential to be generalized to other sectors of the economy. In particular, we believe this study might serve as a model for investigations in other areas, where using a TCT lens to calculate factors to reduced performance, operationalized as financial performance, is useful. Specifically, faced with a variety of contract options, our model may be used as a starting point for managers in a variety of industries to evaluate the risk of lower performance, which can be evaluated along with contract costs to make a decision on governance selection.

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