IT outsourcing and firm-level performance: A transaction cost perspective

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Abstract:

We analyzed the effect of the level of low asset specificity IT outsourcing on firm-level financial performance. We used transaction cost economics (TCE) as the theoretical basis to explain the effect of the level of network and telecommunication services outsourced on financial performance. An analysis of 1444 Integrated Healthcare Delivery Systems revealed that higher levels of network and telecommunication services outsourced were associated with superior financial performance. Specifically, each additional network and telecommunication service outsourced resulted in an average $3,120,000 in savings, a 25% increase in profit. In addition, increases in IT budgetary expenditures were found to be associated with increased financial performance. Our study provided preliminary support for the use of asset specificity to guide outsourcing decisions. In particular, IT activities that have become commodities (having ‘low specificity’) should be outsourced to improve the firm's financial performance.

Keywords: IT outsourcing | transaction cost economics | healthcare | IT governance | services oriented architecture

Article:

1. Introduction

The management of organizational IT is fundamental to organizational success [7]. Outsourcing IT can reduce its overall cost to the firm; this was the focus of our study. Prior IT outsourcing studies have examined a wide variety of topics, including why firms choose to outsource, management and relationship issues associated with it [15], and the performance outcomes associated with it. Our study extended this by empirically analyzing the relationship between the

level and type of IT outsourcing and firm-level financial performance. By understanding the characteristics of IT that make it amenable to outsourcing, we can determine its potential to improve firm performance, allowing firms to make better decisions regarding what type of IT to outsource or insource.

The total value of the IT outsourcing market in North America was estimated at $160 billion in 2005. The make or buy decision for IT services can have a significant impact on the firm's operational efficiency and its bottom-line. One of the foundations of globalization and outsourcing is its communications network. Electronic communication networks allow access to a larger, more diverse range of markets providing organizational IT departments with a range of options when considering whether or not to outsource particular functions. Given their homogeneous, standards based nature, internal networks can be considered commodities that are likely to be more efficiently procured in the marketplace than built internally. Similarly, network management services to operate and maintain the network are IT commodities that can be more efficiently procured in the marketplace.

For the healthcare industry, outsourcing IT functions has the potential to reduce the cost of administering healthcare services. Researchers at Boston University's School of Public Health estimated that $1.9 trillion dollars was spent on healthcare in the United States in 2005, an increase of 48% since 2000 [1]. Administrative costs account for as much as 25% of the expenses [10].

The purpose of our study was to examine the efficiency outcomes associated with outsourcing IT commodities in the healthcare industry to determine whether or not the level of IT commodity outsourcing was associated with better firm-level performance. Specifically, the level of low specificity IT asset outsourcing was assessed and used as a measure of IT as a commodity and then used to determine the correlation between a firm's level of low asset specificity outsourcing and performance.

2. Background and theory development

2.1. IT outsourcing

Gonzalez et al. [8] in a literature review of outsourcing articles published between 1988 and 2005 found that the study of outsourcing determinants and reasons why firms choose to outsource to be the most frequently studied topics in the IS field. Emphasis on the study of determinants has contributed to the understanding of the outsourcing phenomenon; however, few studies have examined the relationship between outsourcing outcomes and the reasons why firms choose to outsource.

Research exploring the realization of outcomes has compared predefined objectives for outsourcing with measures of how well they are satisfied by outsourcing, whereas performance based analysis has examined the efficiency and effectiveness changes that can be attributed to the outsourcing decision.

Two studies examined the relationship between the level of outsourcing and firm-level financial performance. One examined the relationship between large outsourcing announcements and a firm's productivity and profitability, finding that outsourcing was associated with higher levels of productivity and profitability [9]. A second found no relationship between the level of IT outsourcing and firm-level financial performance in Florida hospitals, suggesting that outsourcing is a cost neutral approach for providing organizational IT capability [13]. The difference in the findings of the two studies may be due to the wide variety of advantages, disadvantages, and risk associated with outsourcing and a failure to consider differences in the types of IT resources outsourced.

Outsourcing organizational IT has advantages, disadvantages, and risks – the net gain from outsourcing IT may not be positive. One advantage of IT outsourcing is that it allows an organization to focus on core business competencies rather than administrative functions. Managing a data center and providing IT services to employees is not a core competency of most organizations, To increase the emphasis on the core business, an organization can outsource all or part of its IT operations. A second advantage is the cost efficiency associated with outsourcing due to economies of scale and of experience. Because the third party specializes in IT management, it can provide good service levels at lower cost. Furthermore, purchased services bring assurances of standardized interface and exchange protocols that allow for easier expansions and upgrades.

While the benefits of outsourcing can be significant, there are a number of issues that make it less attractive in some situations. First, the level of organizational control over the IT configurations and services are generally less than those when the system is developed in-house. IT outsourcing requires explicit delineation of the services to be provided from the start and any deviations can add significant costs to the system. The loss of control and decrease in in-house expertise may lead to a decreased level of IT integration in the organization, potentially reducing the competitive advantage of its integrated IT. IT outsourcing puts the support activity outside the organization's internal environment and may result in lower service levels from an end-user's perspective. Furthermore, outsourcing is susceptible to risk factors like antiquated technology lock-in, high-cost of contractual modifications, unanticipated management and transition costs, and legal disputes [3].

The costs, benefits, and risks vary according to the types of IT resources to be outsourced. One theory that can serve as a basis for analyzing the effect of the level of individual IT resources outsourced on the financial performance of the firm is transaction cost economics.

2.2. Transaction cost economics (TCE)

The idea of transaction costs was first proposed to explain why firms choose to make some components and purchase others. The cost for a firm to produce a product or service internally is termed the production cost while the cost of purchasing a product or service is termed a transaction cost. Firms produce a product or service internally when it is economically more cost effective than purchasing the same product or service on the open market. Purchasing a product or service involves an additional cost: that of conducting the transaction. Transaction costs depend on three factors: the frequency of the transaction, uncertainty, and the asset's specificity.

Transaction costs economics makes two primary assumptions about human behavior. The first is that decision makers are bounded rationally. Because they do not have perfect market information; they have to 'satisfice'. The second assumption is that some people engage in opportunistic behavior and it may be necessary for a firm to monitor the other party's performance – adding to the cost of conducting a transaction.

Transactions that have a high frequency of occurrence typically have low transaction costs. Conversely, a high degree of uncertainty contributes to transaction costs. Uncertainty includes the cost associated with searching for information in the market and can represent a significant portion of overall transaction cost as complete information on all prices and products at any given time is impossible. People use satisficing behaviors, choosing the best alternative from the readily available solutions given the information available. A third transaction element relates the rarity and/or complexity of the input being produced.

When two parties attempt to execute a contract, one or both may have to purchase specific assets in order to successfully execute the contract. Assets with specificity are transaction specific and may have very little value in their alternative use. Setup and configuration costs associated with each contract, along with the human knowledge required to execute the contract represent asset specific costs; e.g., custom built supply chain interfaces require intimate knowledge and expertise of the resource in order to maintain and support it. An IT outsourcing firm supporting a firm's custom built software application would incur the cost of acquiring knowledge and expertise to maintain this unique resource. Since the knowledge and expertise acquired is unique to the transaction, it has little value in any other market. Furthermore, assets that are purchased specifically for a transaction make a firm susceptible to opportunistic behavior unless sufficient provisions are specified in the contract and adequate measures are taken to police and enforce its performance. Contracting and monitoring add significantly to the transaction costs, increasing the likelihood that a firm can more efficiently manufacture the product internally.

Aubert et al. [2] developed a transaction cost model of IT outsourcing examining the specific elements of transaction costs and unexpectedly found a positive relationship between asset specificity and degree of outsourcing showing the "non-optimal behavior of some firms."

Significant prior research on IT outsourcing has used TCE to explain the degree of IT outsourcing sometimes finding considerable deviation from theoretical predictions.

The ambiguous results have led some to question the use of TCE to analyze IT outsourcing decisions while others have noted significant empirical support for specific constructs of TCE, such as asset specificity [6]. Since firms are made up of people who are bounded rational due to imperfect information, a firm's decisions to outsource may not always be optimal. Therefore, research using TCE to explain a firm's choice to outsource may not be appropriate because firms do not always choose the best alternative. Self-serving attribution suggests that those that choose to outsource will view outsourcing favorably while those that choose to insource will view insourcing favorably. Accordingly, survey data obtained from outsourcing stakeholders regarding outsourcing outcomes may be biased. Therefore, we used objective, archival data on firm-level financial performance of IT outsourcing in. We examined IT resources with low asset specificity that can be conceptually considered to be commodities.

2.3. IT commodities

While some have argued that all IT is a commodity [5], we take a broader view and posit that there is a continuum ranging from IT commodities to firm specific IT with many functions falling in-between. Certain types of IT, such as IT networking and telecommunication services, are standardized commodities and are described as low specificity assets. Low levels of asset specificity inherently have lower transaction costs because there is a competitive market for outsourcing such IT. Given the prevalence and widespread adoption of standards for networking and telecommunication services they are commodities with low asset specificity, low levels of uncertainty, and a high potential for repeat transactions. They therefore have low transaction costs.

Firms that outsource IT resources in accordance with the concepts of TCE should experience better outcomes when compared to firms that outsource IT resources that are not. Specifically, firms with greater levels of low asset specificity IT outsourcing will experience superior financial performance than firms with lower levels of low asset specificity IT outsourcing. Therefore, due to the low level of transaction costs, firms that outsource a greater number of IT commodities will have superior financial performance. Specifically, we posited:

Hypothesis 1

. As a firm's level of low asset specificity IT outsourcing increases, the financial performance of the firm will increase.

3. Methodology

3.1. Sample

To test our hypothesis empirically, the level of network and telecommunication services outsourced by Integrated Healthcare Delivery Systems (IHDSs) were analyzed. IHDSs are the dominant organizational form in the U.S. Healthcare Industry and consist of one or more health care providers, such as hospitals, nursing homes, acute care specialists, and family practitioners, combined to achieve operational efficiency. Such organizations have already engaged in a significant make-buy decision process by integrating multiple service lines. Furthermore, an IHDS is at an organizational and managerial level where decisions on investments in IT reside; it is the legal entity that most closely corresponds to an organization. The level of networking and telecommunication services outsourced for 1444 IHDSs for the calendar year 2003 were analyzed.

The data was obtained from the Dorenfest Institute for Health Information Research and Education. This Institute conducts an annual survey of IT usage in the U.S. Healthcare Industry and is under the management of the Healthcare Information and Management Systems Society Foundation (HIMSS Foundation).

3.2. Measurement of variables

The dependent variable examined in our study was the financial performance of an IHDS. Since investments in IT can increase revenue as well as decrease costs, a measure that includes both cost and revenue must be used. Specifically, firm-level financial performance will be measured as the ratio of total annual revenue to total annual cost for an IHDS.

The independent variable examined in our study is the level of networking and telecommunication services outsourced. Each IHDS participating in the survey reported the number and type of IT services outsourced. For the 1444 IHDSs responding to the survey, a total of 27 different IT services were outsourced for the calendar year 2003. Appendix C contains a list of the 27 IT services. Of these different IT services, three were identified as networking and telecommunication services: network management, disaster recovery, and PACS storage. The total number of networking and telecommunication services outsourced by each IHDS was used as the measure of the level of low asset specificity IT outsourcing.

To control for potential confounding factors associated with other IT factors affecting firm-level financial performance, four control variables were introduced into the model. Due to the service orientation of the healthcare industry, it was expected that IT investments would have an increasingly important effect on firm-level performance as IT expenditure's effect on financial performance was found to be greater in service industries [11]. Accordingly, the total IT budget was measured using the amount an IHDS spent on IT in a given year as a percent of total operating costs. This type of measure provides an accurate indication of the level of IT expenditure and permitted us to compare large and small IHDSs. The level of IT budgetary expenditures may impact the financial performance of the firm; thus, IT budgetary expenditures

for an IHDS were included as a control variable in the research model so that we could isolate the effect of the network and communication services outsourced on firm-level financial performance.

Characteristics of IT infrastructure that had an effect on the effort required to manage the organization's network and organizational financial performance were controlled for in the analyses. Prior research had found that investment in IT infrastructure had no direct effect on firm competitive advantage [4] while other studies had argued that the value of IT infrastructure was difficult to assess, due to its indirect support for organizational business processes [12]. The value of the IT infrastructure lies in its flexibility in achieving organization strategic objectives.

Given the difficulty that prior studies have had in demonstrating the business value associated with IT infrastructure and the fact that IT infrastructure is homogeneous and easily transferable among organizations, it was expected that differences in firm-level organizational networks would have an effect on firm-level financial performance. Therefore, differences in IT infrastructure were controlled so that the effect of the level of network and telecommunication services outsourced on the firm-level financial performance was isolated. Because network management was one of the services analyzed, firm-level differences in the complexity of organizational services that affected the ability of a third party provider to manage the client's network needed to be taken into account. Firms with simple networks would be easier to manage than firms with complex ones. Accordingly, two indicators of organizational network complexity were included as control variables; these were selected as they account for most organizational hardware within an IHDS and should provide a strong indication of the complexity of the IHDSs network.

The first indicator of organizational network complexity is the number of PCs per employee. Medical professionals are a mobile workforce requiring access to PCs in a variety of settings. Increased availability and access to information leads to improved decision-making, improved communication, more efficient business processes and the potential for improved financial performance and is dependent on the availability and number of PCs. A greater number of potentially redundant PCs to support physician decision-making results in a more complex environment to manage. Hence, the number and availability of PCs as measured by the ratio of the total number of PCs owned by the IHDS to the total number of employees in the IHDS is included in the research model as a control variable.

The second indicator was the level of data center integration. It has been argued that investment in IT infrastructure can reduce complexity and provide better support in high growth firms by reducing the cost of operations [14]. Therefore, investments in IT infrastructure that reduce back office equipment required to support the organization is likely to improve the financial performance of the firm. Organizations with simpler, less complex data centers should

experience superior financial performance. Furthermore, organizations with fewer servers per employee have higher levels of integration due to the presence of a smaller number of specialized applications, which typically require extensive customization to integrate into existing IT systems and typically cost more to operate and manage than a comprehensive system, such as ERP. To measure the level of data center integration, we computed the ratio of the total number of servers to the total number of employees. Organizations with higher levels of data center integration have fewer servers in their data centers, resulting in a lower ratio. Higher levels may lead to increased financial performance and are simpler network environments, requiring less effort to manage. Hence, the level of data center integration for an IHDS was included in the model as a control variable.

The final type of IT resource for which we controlled was the level of IT personnel. The capability of the IT staff may affect firm-level financial performance. IT personnel may significantly increase the financial performance of the firm by providing technical expertise and business knowledge to develop integrated solutions that are unique in the firm. Furthermore, IT staff can enable others in the organization to do their jobs more effectively, leading to increased financial performance. In addition, higher levels of IT staff will have greater knowledge of the systems and their configurations, leading to better system integration. This may provide competitive advantage; it is thus possible that larger numbers of IT staff will lead to increased financial performance. Hence, the level of IT personnel is incorporated in the model as a control variable.

Table 1 shows the constructs of the dependent, independent, and control variables in our model and provides a summary of how each will be measured.

Table 1. Description of model constructs and measures.

Construct	Type	Description and measure
Financial performance	Dependent	Measured as the ratio of total annual revenue divided by total annual operating cost
Level of low asset specificity IT outsourcing	Independent	The total number of network and telecommunication services outsourced by an IHDS
IT budget	Control	The % of total operating budget spent on IT for an IHDS
PC availability	Control	Employee access to PCs measured as the ratio of the number of PCs owned by the IHDS divided by its total number of employees

Construct	Type	Description and measure
Data center integration	Control	The level of integration in an IHDS data center measured by the ratio of the total number of servers operated by the IHDS divided by the total number of employees
IT personnel	Control	The capability of the IT staff for an IHDS measured by the ratio of IT staff to total number of IHDS employees

3.3. Analysis

We tested the model using regression analysis. Eq. (1) shows the regression model and incorporates the variables:

$$\log(\text{RevCost})=\beta_0+\beta_1\times\text{OutsourcedServices}+\beta_2\times\text{ITBudget}+\beta_3\times\log(\text{PCRatio})+\beta_4\times\log(\text{ServerRatio})+\beta_5\times\log(\text{ITStaffRatio})+e$$

The model examined the effect of the level of outsourced services on a firm's financial performance while controlling for the level of expenditures on IT, the availability of PCs, the level of IHDS data center consolidation, the complexity of the organizational network, and the level of IT staff.

4. Results

The descriptive statistics for the variables of interest can be found in Appendix A. After preliminary analysis of the scatter plots of the ratio variables and the identification of significant outliers, the ratio variables were log transformed. Maximum likelihood estimation was then used, as opposed to ordinary least squares, in order better to account for the presence of extreme outliers. Table 2 is the correlation matrix for the log transformed variables of interest. As shown in the correlation matrix, the correlation between the variables is within acceptable ranges indicating that multicolinearity should not be a factor in the analysis.

Table 2. Correlation matrix.

	Ratio of total revenue to total cost	Outsourced network services	IS budget	PC ratio	Server ratio	IT staff ratio
Ratio of total revenue to total cost	1.00	0.062	0.089	0.055	0.005	0.070
	–	0.033	0.007	0.079	0.875	0.017
	1193	1193	920	1040	1028	1160
Outsourced network services	0.062	1.00	0.044	0.081	0.079	−0.0034
	0.033	–	0.139	0.005	0.007	0.900
	1193	1444	1110	1199	1186	1342
IS budget	0.089	0.044	1.00	0.253	0.203	0.283
	0.007	0.139	–	<.0001	<.0001	<.001
	920	1110	1110	967	959	1058
PC ratio	0.055	0.081	0.253	1.00	0.455	0.479
	0.079	0.005	<.001	–	<.0001	<.001
	1040	1199	967	1199	1180	1181
Server ratio	0.005	0.079	0.203	0.455	1.00	0.442
	0.875	0.007	<.0001	<.0001	–	<.001
	1028	1186	959	1180	1186	1169
IT staff ratio	0.072	−0.031	0.283	0.479	0.442	1.00

	Ratio of total revenue to total cost	Outsourced network services	IS budget	PC ratio	Server ratio	IT staff ratio
	0.017	0.252	<.001	<.001	<.0001	–
	1160	1342	1058	1181	1169	1342

Results from the regression analysis show the R^2 for the model to be 0.0078 indicating that variation in the log of the ratio of total revenue to total cost is explained by network and communication services outsourced, IT budget, ratio of PCs to employees, ratio of servers to employees, and the ratio of IT staff to employees. While the R^2 is less than desired, it is important to note that the response variable is the log of the ratio of total revenue to total cost and many factors other than IT influence on financial performance and that the primary purpose of the study was to explain the relationship between IT outsourcing and firm-level financial performance. The low R^2 does not negate the managerially significant and theoretically insightful relationship between IT outsourcing and firm-level financial performance.

To further justify the appropriateness of the full model, a likelihood ratio test was performed. Results of the likelihood ratio test indicate the full model specified in Eq. (1) is statistically different from a reduced constant model lending support for the full model and a detailed analysis of the individual effect of each parameter on the response variable. Appendix D contains a detailed description of the likelihood ratio test.

Table 3 shows the results from the regression analysis and summarizes the parameter estimates for the model along with the significance of each parameter estimate.

Table 3. Nonlinear likelihood parameter estimates.

Hypothesis	Parameter	Estimate	Approx. SE	Approx. *t*-Value	Pr > |*t*|
	β_0	0.0050	0.0146	0.34	0.7328
H1	β_1^*	0.0096	0.0039	2.49	0.0130
Control	β_2^{**}	0.0036	0.0012	2.98	0.0029
	β_3	0.0030	0.0027	1.11	0.2662

Hypothesis	Parameter	Estimate	Approx. SE	Approx. *t*-Value	Pr > |*t*|
	β_4	−0.0003	0.0017	−0.17	0.8654
	β_5	0.0001	0.0034	0.04	0.9688
	S(*y*)	0.0275	0.0017	16.28	<0.0001
	df	1.477	0.1415	10.44	<0.0001

* Significant at 0.05 level.
** Significant at 0.01 level.

As shown in Table 3, the parameters β_1 and β_2 are significant. The coefficient β_1 corresponds to the number of network and communication services outsourced while β_2 is associated with the IT budget. None of the other parameters were found to be significant.

The estimated size of the effect of each parameter was also listed in Table 3. While the estimates for the significant parameters appeared to be fairly small, it is important to note that they are predicting the log of the ratio of total annual revenue to total annual cost and that differences associated with changes in the significant parameters have managerially significant consequences for an organization. Specifically, the relationship between the total number of IT services outsourced and financial performance was positive and significant such that IHDSs with more IT services outsourced had better financial performance.

The results indicated that each additional network and telecommunication service outsourced was associated with an increase of between $2,200,000 and $4,400,000 in profit for an average sized IHDS. Similarly, the level of IT budget was found to have a significant and positive effect on financial performance such that each one tenth of 1% increase in IT budgetary expenditures resulted in an increase in profit of between $83,000 and $166,000 for an averaged sized IHDS (based on an average size IHDS with $332,600,000 in revenue and $320,000,000 in expenses while holding all other predictor variables fixed at their mean). Appendix B contains a detailed illustration of the computation for the change in profit associated with incremental increases in IT budget and IT outsourcing, respectively.

5. Discussion

Previous studies have produced mixed results on the effects of outsourcing low asset specificity IT on firms' financial performance. The main contribution of our study was the identification of the level of low asset specificity IT outsourcing as a predictor of financial performance for organizations in the Healthcare Industry using a large sample of firms. While prior research had found mixed support for the financial performance of IT owned and operated by an organization, our research suggests that outsourcing IT is an approach for improving the financial performance

of the firm in the healthcare sector. Findings also extend the literature by highlighting the benefits of increased total IT budgetary expenditure.

5.1. Theoretical implications

Unlike prior research, our study found empirical support in demonstrating the value of IT outsourcing using transaction cost economics as a theoretical lens. Rationally bounded people face the 'make-or-buy' decision in highly complex, uncertain environments; they may not therefore make optimal decisions limiting the ability of TCE as a way to explain outsourcing decisions. Our study showed that TCE constructs corresponded closely to optimal allocation of firm-resources so that firms that outsource low asset specificity resources experience superior financial performance providing valuable support for normative value of TCE. Internal IT that is low in asset specificity has a greater cost than IT that is outsourced resulting in greater financial performance of low asset specificity IT that is outsourced. Findings lend preliminary support for organizations to look first to shift low asset specificity IT to outsourced vendors prior to investing in internal IT.

5.2. Managerial implications

These findings have important managerial implications for Integrated Healthcare Delivery Systems in the Healthcare Industry. Results indicate that if two large populations of IHDSs exist, one with one network and telecommunication service outsourced and the other with two network and telecommunication service outsourced; both have populations with an average of $333 million in revenue while holding IT budget, PC ratio, server ratio, and IT staff ratio fixed at their mean values, one would expect profit (revenue while holding costs fixed) to lie between $2,201,184 and $4,424,682 more for the population with two network and telecommunication services outsourced than those with one network and telecommunication service outsourced. This is significant and has direct and important consequences.

Of course, increases in IT budgetary expenditures and the number of IT services outsourced are associated with increases in profit.

6. Conclusion

The primary objective of our study was to answer the research question: do firms with higher levels of IT outsourcing of resources that are low in asset specificity experience higher financial performance than firms with lower levels of asset specificity in the Healthcare Industry?

By analyzing network and telecommunication services outsourced while controlling for IT budgetary expenditures, organizational network complexity, and the ratio of IT staff to total number of employees for 1444 IHDSs, a test of the significance of each of these parameters was performed. Network and telecommunication services outsourced were found to affect financial performance significantly, as measured by the ratio of total revenue to total annual costs.

Results from our study show how increased numbers of network and telecommunication services outsourced are associated with firm-level financial performance such that each additional network and telecommunication service outsourced is associated with approximately $3,120,000 in increased profit corresponding to a 25% increase in profit. Furthermore, our study suggested that the number of network and telecommunication services outsourced and the level of IT budget positively affected performance while the level of IT infrastructure and IT personnel did not. These findings have important managerial implications. Organizations should dramatically expand their level of IT outsourcing and reduce their level of investment in internally owned and operated IT commodities.

Of course, this study had some additional limitations. One involved the fact that the data are from a single industry. A second concerned the low R^2 of the model. While it was shown to be statistically different from a constant model, it explains a low proportion of firm-level financial performance. A third limitation concerns the fact that only the effect of low asset specificity outsourcing on firm-level financial performance was analyzed. We provide preliminary support for the use of asset specificity to guide outsourcing decisions and strong evidence that low asset specificity outsourcing is associated with increased firm-level financial performance. Overall, these findings will aid managers in restoring their firms to financial health.

Appendix A. Descriptive statistics for baseline variables

Table A.1 lists the baseline variables used in the study along with descriptive statistics for each variable. *N* indicates the number of Integrated Healthcare Delivery Systems (IHDSs) answering each question out of a possible total of 1444. Data is from a survey on IT usage in the U.S. Healthcare Industry conducted by the Dorenfest Institute for calendar year 2003.

Table A.1. Descriptive statistics for baseline variables (2003).

Variable	*N*	Mean	SD	Minimum	Maximum	Skewness	Kurtosis
Profit	1228	10.5 million	105 million	−400 million	2.54 billion	−18.25	400.2
Annual net revenue	1255	333 million	913 million	1 million	19.7 billion	11.88	206.7
Annual operating cost	1237	320 million	868 million	607 thousand	19.1 billion	11.86	209.7
Total number of employees	1383	3357	9371	25	185,000	10.83	159.2

Variable	*N*	Mean	SD	Minimum	Maximum	Skewness	Kurtosis
Total number of IT employees	1399	63	325	0.25	8,500	19.77	443.4
Number of PCs	1262	1360	2453	0	50,000	8.22	130.0
Number of servers	1256	50.6	114	0	3,000	15.49	364.5
IS budget	1110	2.25	1.15	0.5	6.50	1.34	2.926
Number of services outsourced	1444	1.26	1.43	0	17	2.40	13.91
Number of network services outsourced	1444	0.11	0.36	0	3	3.63	14.77

Appendix B. Prediction interval estimations

B.1. IT budget

Fig. B.1 is a sensitivity analysis for the prediction interval for IT budget in the study for an average size IHDS with $333 million in revenue and $320 million in costs. Nonlinear maximum likelihood parameter estimates for the regression model are used to estimate changes in profit associated with changes in IT budgetary expenditures holding network and communication services outsourced, the natural log of the PC ratio, the natural log of the server ratio, and the natural log of the IT staff ratio fixed at their mean values of 0.11, −0.825, −4.14, and −4.28, respectively.

Figure B.1 is omitted from this formatted document.

B.2. Network and communication services outsourced

Fig. B.2 is a sensitivity analysis for the prediction interval for network and communication services outsourced for an average size IHDS with $333 million in revenue and $320 million in costs. Nonlinear maximum likelihood parameter estimates for the regression model are used to estimate changes in profit associated with changes in IT budgetary expenditures holding IT

budget, the natural log of the PC ratio, the natural log of the server ratio, and the natural log of the IT staff ratio fixed at their mean values of 2.25, −0.825, −4.14, and −4.28, respectively.

Figure B.2 is omitted from this formatted document.

Appendix C. IHDS IT services outsourced

IT service outsourced

Hardware maintenance and support

IT application development

IT application implementation

PACS implementation

Web site development and support

HIPAA related

Patient safety assistance

Remote processing and remote ASP offerings

Transcription

Help desk support

Disaster recovery

Network management

PACS storage

Benefits realization

Cost reduction project

IT assessments and reviews

IT contract staffing

IT plans and strategies

IT subject matter expertise

IT systems selection

Interim IT department outsourcing

Long term IT department outsourcing

Other IT project management contract

PACS evaluation

PACS selection

Work process improvement and re-engineering

Other

Appendix D. Likelihood ratio test

To further justify the appropriateness of the full model, a likelihood ratio test was performed comparing the full model with a reduced constant model represented by Eq. (2):

(2)

$\log(\text{RevCost}) = \beta_0 + e$

In a likelihood ratio test, the ratio of the maximum log likelihood of the reduced model is calculated and compared to the maximum log likelihood of the full model to test the null hypothesis that all parameter values are equal to zero. If the maximum log likelihood of the reduced model is not statistically different than the maximum likelihood of the full model, then use of the full model is not warranted, as the full model is no better fit than a constant model.

Specifically, the null and alternative hypotheses were:

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$

and

H_1: Not all $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, $\beta 5$ are 0

The resulting ratio is distributed according to the chi-square distribution with the degrees of freedom equal to the difference between the number of parameters in the full model and the reduced model. The results were as follows:

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Log likelihood full model (Eq. (1)) = LL_F.

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Log likelihood reduced model (Eq. (2)) = LL_R.

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$LL_F = 1182$.

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$LL_R = 1172$.

The test statistic, T_{stat}, was calculated from the following equations:

$$T\text{stat} = -2 \times [\text{LLR} - \text{LLF}]$$

$$T\text{stat} = -2 \times [1172 - 1182]$$

$$T\text{stat} = 19.2$$

The degrees of freedom for the chi-square distribution were calculated by taking the difference between the number of nonconstant parameters in the full model and the number of nonconstant parameters in the reduced model. Specifically,

$$\text{degrees of freedom} = (\#\ \text{parameters})_{\text{Full}} - (\#\ \text{parameters})_{\text{Reduced}}$$

$$\text{degrees of freedom} = 5 - 0 = 5$$

Next, the *p*-value was computed for the test statistic using a chi-square distribution with 5 degrees of freedom.

$$p\text{-value} = \text{chi-square}\ (19.2,\ 5) = 0.002$$

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