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ANALYZING OPTIMAL IT INVESTMENT IN TERTIARY CARE HOSPITALS OF PUNJAB USING DATA ENVELOPMENT ANALYSIS

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Abstract: *The influence of IT investment on hospital efficiency and quality are of great interest to health care executives as well as insurers. Few studies have examined how IT investments influence both efficiency and quality or whether there is an optimal IT investment level that influences both in the desired direction and contribute to economy. Rising awareness and disposable income has accelerated the growth of health care. Private sector hospitals in India are facing the immense pressure for cost-reduction and better treatment. In order to become efficient and competitive, these hospitals have to provide medical services of international standard at affordable prices. According to Report published by Deloitte in 2013 on Indian health care system India need to Add 1 million more beds in next 5 years in order to reach patient Bed ratio equivalent to US 1:250 which is currently 1:1050 .It is not an easy task to add resources to existing setup at much faster pace because other economic development activities are going on in parallel ,There is a need to develop an approach to assess the operational efficiency of the health care Centre's and set some benchmark for efficiency so hospitals will operate more efficiently using existing resources. In view of this, the study focused on data collected from tertiary care hospitals in Doaba area of Punjab and data published between 2002 to 2014 for analyzing 'sweet spot' of IT investment using DEA analysis at which both operational efficiency and service quality of hospitals are maximized and contribute toward betterment of economy.*

Keywords*: DEA, Operational Efficiency,Sweet spot, benchmark, Economy ,IT investment*

JEL Classification: *I100*

INTRODUCTION

Given the health-financing situation it has become imperative for health facilities in Punjab to ensure more efficient means of providing services. In the present scenario, there is very little price competition and little incentive to contain costs and ensure efficiency. However, the budget constraint forces many of these institutions to provide more services for a given level of resources. Under the present circumstances, it is essential to find out the appropriate resource mix and its utilization. Similarly, it is necessary to identify the sources of relative cost

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inefficiency – technical and allocate both. The focus of this paper is on assessing the hospitals in technical terms, i.e. the right amount of inputs to produce a given level of output using IT.

There is a sizable literature investigating the business value of IT for different industries. However, the business value of IT in health care is still to be fully investigated (Devaraj, Ow, & Kohli, 2013; Haddad, Gregory, & Wickramasinghe, 2014). Demonstrable return on investment for health care IT is essential to convincing hospital managers that IT investment can improve their performance. Hospital managers must also decide how and where to deploy IT – in quality enhancing initiatives or efficiency bearing initiatives, or both? Given mounting pressures to control costs, and because IT constitute a significant cost, managers must understand the available choices in order to make appropriate IT investment decisions (Salge, 2011).

TRENDS IN HEALTH INFRASTRUCTURE IN PUNJAB

Assuring a minimal level of health care to the population is a critical constituent of the development process. Since health as a social good provides externalities, large-scale health facilities can only be provided with public resources Punjab, as such, does not have any specific health policy of its own. Health programs in the state, as in most of the other Indian states, have continued to pursue, the policies of the Union Government. Prior to the beginning of the Fourth Five Year Plan, efforts had already been made to expand the health services to meet the requirements of the people of the state, according to the guidelines laid down by the Union Government.

Punjab government has put in place an elaborate and extensive network of health facilities in both rural and urban areas. Table 1.1 presents the data on the number of medical institutions classified by the type of institutions (hospitals, PHCs, dispensaries and others) in Punjab and their rural-urban distribution for the period 1981-2008. During the first period, the rural areas witnessed a decline in the number of hospitals and number of dispensaries depicting negative growth rates i.e. -2.10 per cent per annulment -0.92 per cent per annum respectively. The urban areas also witnessed negative growth rate in case of hospitals (-0.04 per cent per annum) while the dispensaries grew at the rate of 0.81 per cent per annum.The number of PHCs increased in rural and urban areas both. But a higher growth rate was recorded for rural areas (5.58 per cent per annum) as compared to that of urban areas (1.08 per cent per annum). The data regarding number of other medical institutions was collected only after 1990. The data revealed that during 1990-2008, the other medical institutions grew at a higher rate in rural areas (1.67 per cent per annum) as compared to that in the urban areas (1.43 per cent per annum).

Table 1
Classification of Public Medical Institutions by Location and Ownership in Punjab (in number)

Year	*Public Medical Institutions Owned By*			*Public Medical Institutions Located In*		
	State Govt.	*Local Govt.*	*Vol.Org.*	*Rural Area*	*Urban Area*	*Total*
1981	1772	49	47	1509	359	1868
1982	1982	47	47	1710	366	2076
1983	2041	47	47	1758	377	2135
1984	2079	46	47	1792	380	2172
1985	2085	46	47	1792	386	2178
1986	2086	46	55	1796	391	2187
1987	2094	46	55	1798	397	2195
1988	2106	40	51	1797	400	2197
1989	2110	36	51	1797	400	2179
1990	2128	25	51	1799	405	2204
1991	2128	25	51	1799	405	2204
1992	2141	25	51	1800	417	2217
1993	2141	25	51	1775	442	2217
1994	2144	25	51	1775	445	2220
1995	2144	25	51	1775	445	2220
1996	2152	25	51	1775	453	2228
1997	2153	25	51	1776	453	2229
1998	2153	25	51	1776	453	2229
1999	2153	25	51	1776	453	2229
2000	2153	25	51	1776	453	2229
2001	2153	25	51	1776	453	2229
2002	2172	24	50	1776	470	2246
2003	2168	24	50	1774	468	2242
2004	2168	24	50	1774	468	2242
2005	2168	24	50	1774	468	2242
2006	2151	24	50	1771	454	2225
2007	2154	24	50	1764	464	2228
2008	2154	24	50	1764	464	2228
Compound Annual Growth Rate (per cent)						
1981-2009	0.33	-2.93	0.11	0.10	0.99	0.21
1981-1990	1.36	-5.14	1.48	1.20	1.34	1.16
1991-2000	0.08	0.00	0.00	-0.08	1.06	0.07
2001-2009	-0.11	-0.03	-0.16	-0.14	0.16	-0.16

Source: Statistical Abstract of Punjab, Various Issue

The growth in number of beds in various type of medical institutions (hospitals, PHCs, dispensaries and others) in Punjab's rural as well as urban areas for the period 1981-2008 has been presented in Table 5.4. The total number of beds in medical institutions increased from 20569 to 25489 during 1981-2008 showing a growth rate of 0.67 per cent per annum. There has been an increasing trend in the number of beds in rural and urban areas the beds in urban areas grew at a higher rate i.e. 0.88 per cent per annum as compared to that of the rural areas (0.39 per cent per annum) during the corresponding period. The maximum growth in the number of beds has been recorded during the first period in case of both rural and urban areas. During 1981-1990, the increase in number of beds in medical institutions was found to be higher in rural areas (1.74 per cent per annum)as compared to that of the urban areas (1.69 per cent per annum). But during 1991-

Table 2
Beds in Punjab, by Area and Type of Medical Institutions

(in number)

Year	*Beds in*		*Beds Installed in*				
	Rural	*Urban*	*Hospital*	*P.H.C*	*Disp.*	*Others*	*Total*
1981	8818	11751	14269	598	5702	-	20569
1982	9662	11800	14332	600	6330	-	21462
1983	9850	11820	14327	600	6743	-	21670
1984	9974	12104	14607	600	6871	-	22078
1985	9980	12124	14617	600	6887	-	22104
1986	10348	12458	15181	686	6939	-	22806
1987	10423	12890	15719	804	6790	-	23313
1988	10498	13314	16084	1362	6366	-	23812
1989	10591	13319	16094	1826	5990	-	23910
1990	10702	13477	14472	1842	5531	2334	24179
1991	10702	13477	14472	1842	5531	2334	24179
1992	11036	13706	14069	1734	5523	3416	24742
1993	10627	14115	14069	1786	5471	3416	24742
1994	10627	14265	14219	1786	5471	3416	24892
1995	10627	14265	14219	1786	5471	3416	24892
1996	10627	14397	14319	1786	5511	3416	25032
1997	10653	14397	14319	1786	5503	3442	25050
1998	10671	14423	14319	1774	5499	3502	25094
1999	10806	14501	14319	1728	5458	3802	25307
2000	10832	14545	14319	1728	5458	3872	25377
2001	10832	14522	14296	1728	5458	3872	25354
2002	10787	14605	14875	1758	5651	3108	25392
2003	10747	14545	14815	1758	5611	3108	25292
2004	10647	14545	14815	1758	5511	3108	25192
2005	10647	14545	14815	1758	5511	3108	25192
2006	10751	14738	14865	1758	5501	3373	25489
2007	10743	14746	14865	1758	5493	3373	25489
2008	10743	14746	14865	1758	5493	3373	25489
Compound Annual Growth Rate (per cent)							
1981-2009	0.39	0.88	-0.04	4.28	-0.76	0.86*	0.67
1981-1990	1.74	1.69	1.04	14.97	-0.62	-	1.81
1991-2000	0.03	0.81	0.11	-0.41	-0.14	3.44	0.37
2001-2008	-0.14	0.22	0.27	0.18	-0.16	-0.32	0.14

Source: Statistical Abstract of Punjab, Various Issue

2000, the increase was higher in urban areas (0.81 per cent per annum)as compared to rural areas (0.03 per cent per annum). And during 2001-2008, it has been observed that the number of beds in rural areas declined (-0.14 per cent per annum) but their number slightly increased in urban areas (0.22 per cent per annum).

Table 3
Population Served per Medical Institution, per Bed & Area Covered per Institution (in kms) in Punjab

Year	*Population Served Per* *Medical Institution*	*Bed*	*Average Radius Served perInstitution (in kms)*
1981	8997	817	2.929
1982	8275	800	2.778
1983	8291	821	2.740
1984	8344	840	2.726
1985	8524	840	2.712
1986	8724	838	2.712
1987	8905	840	2.707
1988	9110	837	2.706
1989	9291	854	2.706
1990	9484	864	2.696
1991	9245	844	2.696
1992	9307	834	2.688
1993	9479	850	2.688
1994	9741	869	2.687
1995	9873	881	2.687
1996	10053	895	2.682
1997	10218	909	2.681
1998	10383	922	2.681
1999	10584	932	2.681
2000	10786	947	2.681
2001	10896	957	2.681
2002	10893	964	2.669
2003	11095	984	2.680
2004	11461	1020	2.680
2005	12176	1083	2.680
2006	11940	1042	2.680
2007	11397	955	2.683
2008	12335	1078	2.683

*Source:*Statistical Abstract of Punjab, Various Issue

Though it has been revealed in the data presented earlier that during the study period there has been a decent increase in the number of medical institutions and also in the number of beds in the medical institutions in Punjab, but this analysis presents an incomplete picture unless we present the data revealing the population served by these medical institutions and the beds. As there has been growth in health infrastructure there has also been increase in the population of Punjab so it becomes necessary to analyze the data with respect to population served per medical institution and per bed. Therefore, Table 5.5 presents the data on population served per medical institution and population served per bed for the period 1981-20.

DATA ENVELOPMENT ANALYSIS

The study uses DEA (Data Envelopment Analysis) approach to analyses the data. In light of the points made in the background for this paper, it was essential to use a methodology that could assess and compare efficiency between these two categories of hospitals. Or, in other words, the tool used for the analysis should be compatible for both categories. This is where the use of DEA became imperative. The other reason for use of DEA as an analysis tool was the flexibility of DEA in handling multiple input and output measures, which was required essentially in this study. On the flip side, however, it has been found that researchers have been reluctant to use DEA as an analysis tool since it lacks a crucial error term (Valdmanis 1992). However, in DEA the selection of functional form is not the main consideration but to choose the right input and output variables since the model is non-parametric and derives the input-output production correspondence using linear programming techniques. The first research question driving this study is ''Can hospitals improve their operational efficiency as well as health care quality by investments in information systems?'' Further, we identify the interplay of efficiency and quality and identify characteristics of the hospitals that can better take advantage of their IT investments. Hence, the second research question is, ''what is the optimal balance of efficiency and quality relative to IT investment? In other words, 'what is the 'sweet spot' of IT investment at which both operational efficiency and service quality are maximized? 'In addition to seeking answers to the above research questions, we aim to contribute to the literature with an alternative methodological approach based upon a two-stage double bootstrap data envelopment analysis (DEA), in line with Samar and Wilson(2007). Wu and Hu (2012) proposed a research model for exploring KM-enabled performance for hospital professionals and they found that hospital professionals were closely associated with KM-enabled performance in providing high-quality health care. More recently, Deva raj *et al.* (2013) examined the role of IT on patient flow and its consequences for improved hospital efficiency and performance. They analyzed data from 567 hospitals in U.S. and the results suggested that IT was associated with swift and even patient flow, and consequently with improved revenues. Devaraj et al. (2013) also found that the improvement in financial performance was not at the expense of quality. In another study, Menon and Kohli (2013) investigated the impact of past IT spending on the malpractice insurance premium and the moderating effect of past IT expenditure on the relationship between past malpractice insurance premium and current quality of health care. They found that past IT expenditure was negatively associated with malpractice insurance premium and positively associated with quality of patient care. More recently, Haddad et al. (2014) argued that there is no clear framework for assessing the business value of IT in health care. They proposed a framework for the evaluation of cost versus quality outcomes utilizing different layers within health care delivery. Hence, Hvenegaard et al. (2011) propose a U-shaped relationship between operational efficiency and health care quality. They argue, this U-shaped relationship explains the lack of agreement on the relationship between the two measures of performance found by previous empirical studies. The findings of previous studies depend on where hospitals lie along the U-shaped curve, and how quality was measured.

Based on above discussion we test the following three propositions:

Proposition 1. *Higher levels of IT investments are associated with higher levels of health care quality in hospitals.*

Proposition 2. *Higher levels of IT investments are associated with higher levels of operational efficiency in hospitals.*

Proposition 3. *Higher levels of IT investments and higher levels of health care quality are associated with higher levels of operational efficiency in hospitals.*

DATA SOURCES

The data for this study consist of a panel of 10 tertiary care hospitals in the Punjab IT expenditure variable includes expenses on information systems that are related to direct patient care and covers IT hardware, software, and services. Hospital quality: Measures of hospital quality that are normally used by previous literature are ''risk-adjusted mortality'' and ''complications' 'to explain the differences in the patients.

Hospital efficiency: Efficiency can refer to either ''technical efficiency'' or ''cost efficiency''. Technical efficiency is related to the term productivity. Cost efficiency, instead, takes the costs of inputs into account and describes how much a hospital spends on its inputs to produce a given level of output. In this paper, we refer to technical efficiency, which characterizes efficient behavior to minimize inputs used for a given level of output or maximizing output for a given level of inputs in a hospital. Case Mix Index: The Case Mix Index (CMI) measures how costly and complex inpatients are. The higher the case-mix, the more complex the services offered by the hospital. This captures the hospital-specific systematic variance due to expertise and specialized services. A hospital's CMI is calculated for reimbursement for services by Medicare.

Teaching status: Teaching status is a dummy variable representing a teaching hospital versus non-teaching hospital. Teaching hospitals are more likely to have high-tech medical equipment, higher funding, higher expertise of personnel, and higher severity of cases. The teaching status controls for differential access to technology and expertise within hospital. Hospital location: Similar to teaching status variable, location is a dummy variable which takes a value 1 for urban and for rural areas. Location is expected to impact the types of cases that a hospital takes more frequently.

ESTIMATING EFFICIENCY

Stage 1: Estimating technical efficiency

'A firm uses different kinds of inputs such as capital, labor, materials and produces outputs through a ''production process''. The production frontier specifies the maximum output achievable by employing a combination of inputs. The distance between the maximum output and the actual output is regarded as its ''technical inefficiency''. Therefore, a technically inefficient firm operates below the frontier and a technically efficient firm operates on the production frontier. The two well-known modeling methods of comparative performance measurement are ''non-parametric'' method, characterized by data envelopment analysis (DEA) and ''parametric'' approach, characterized by Stochastic Frontier Analysis (SFA). Both DEA and SFA approaches are derived from the methods of measuring efficiency introduced by Farrell (1957) who suggested measuring the production efficiency of a firm relative to an empirical production frontier. The parametric approach (SFA), involves the assumption of a functional form (e.g. Cobb–Douglas, trans log, CES, etc.) to be made for the production frontier. It uses statistical methods to estimate the coefficients of the production function as well as the technical efficiency (Lovell, 1993). A potential disadvantage of this method is the misspecification of a functional form for the production process. On the other hand, non-parametric production frontiers are based on deterministic mathematical programming and do not make any assumptions about the functional form (Charnels, Cooper, Golany, Seiford, & Stutz, 1985; Giraleas, Emrouznejad, & Thanassoulis, 2012). The data points are compared with one another for determining efficiency and the most efficient observations are used to construct the piece-wise linear convex non-parametric frontier. Consequently, non-parametric production frontiers are employed to measure relative technical efficiency among observations.

Both approaches have well known advantages and disadvantages. The DEA, as developed by Charnes, Cooper, and Rhodes (1978) enable measurement of efficiency for production units (such as hospitals here), using multiple inputs to produce multiple outputs, and it is free of functional assumption but does not control for the random changes. DEA has been used in variety of applications both in public and private sectors (see De Nicola, Gitto, and Mancuso (2012), Emrouznejad and De Witte (2010), Lin, Lee, and Chiu (2009)). The SFA method, however, takes into account the random changes by decomposing the total stochastic term into the firm related and out-of-control factors, but imposes strong assumption on the production process and the error distribution.

Investigating the impact of IT on operational efficiency and health care quality is challenging since health care is a service industry and input–output variables for production function must be defined very carefully in service industries. Our analysis begins with estimating measures of efficiency, technical change, and productivity for each hospital in the sample.

DEA has been widely used in assessing health care centers and hospitals (for example see Field andEmrouznejad (2003),Kirigia, Emrouznejad, Vaz, Bastiene, and Padayachy (2008) and Hollingsworth (2003)). Input and output variables used in this paper are similar to those used in the previous hospital efficiency literature. Output is defined as income and health services. Four direct hospital outputs were specified including: NPR (net patient revenue), IPRev (total inpatient revenue), Admisn (total number of admissions), and IPDays (total number of patient days).For the input set, four variables representing resource consumption are defined: AG_sum (administrative and general direct expenses and salaries), SalWg (salaries wages and fees payable, e.g. for temporary nurses), FTEadj (total number of full time employees), Asst (sum of total current and total long-term assets of the hospital, total assets is a measure of a hospital's size) and Beds (total number of beds in service). A summary of all variable definitions is provided in Table 1. Note that the first three inputs are labor while the last two are proxy for net capital assets, as suggested by Gross Kopf and Valdmanis (1987). For the efficiency scores we used radial measure as calculated by DEA-bootstrapping two-stage approach under variable returns to scale. The bootstrapping procedure applied in this study is based on Simar and Wilson's (2007) to construct estimated confidence intervals for each hospital.

RESULTS AND DISCUSSION

The results which tests for Proposition 1, are presented. In this case, IT and quality are linearly related. An alternative non-reported model specification rejected he non-linear relationship. Results in column (1) and (3) are the baseline specification for both measures of quality in terms of mortality and complications respectively (RAMI and RACI). In the case of quality in terms of risk-adjusted mortality (RAMI) we find a positive and significant relationship between IT and quality (column 1). The negative sign of the IT coefficient implies that higher the IT investment, lower is the mortality index, and therefore higher the quality. As regards to other control variables, the case mix (CMI) negatively affects quality and, teaching hospitals appear to experience a lower quality than non-teaching hospitals.. The results confirm the positive impact of IT on quality. The results also show that the length of stay exert a negative effect on quality. In column (3), we present the results for the baseline specification in which the dependent variable is a measure of quality in terms of complications. In this case, the relationship between IT and quality appears non-significant. In column (4), the previous no significant relationship between IT and quality in terms of complication appears robust to the inclusion of additional control variables. Therefore, our results suggest that IT has a positive and significant relationship with quality only in the case of mortality but not in the case of complications.

Determinants of efficiency: IT and quality

In Table we present the results of testing for Proposition 2. For comparative purposes, column (1) and (2) presents the results from a bootstrap To bit model while those from columns (3) and (4) are those from a bootstrap truncated regression. Results reveal that while the signs of the parameters are maintained, their values change significantly. In column (1) and (3) the baseline specification is presented, in which we regress IT, IT-squared and other controls on efficiency. The results confirm the non-linear U-shaped relationship between IT and efficiency. The coefficients on IT as well as IT-squared are highly significant, and while the coefficient on IT is negative, the coefficient on IT squared is positive. This means that the relationship between IT and efficiency is non-linear. At low levels of IT investment the Relationship is negative, but there is a threshold level of IT at which the relationship becomes positive. Moreover, the differentiation of Eq. (2) with respect to IT yields the slope of the relationship between efficiency and IT. If we calculate the point at which the slope of this relationship is zero, we will have identified the minimum or turning point, of the IT-efficiency relationship.

This level of IT spending is well above the average, what implies he need for hospitals to surpass a high level of IT spending from which additional IT spending brings efficiency improvements. In Fig. 1 we present this U-shaped relationship between the predicted efficiency levels and IT together with its 95% confidence interval. The graph is based on the estimates presented in column (3) of Table 4. The downward slope in the U-shaped curve indicates a negative relationship between lower IT investment and lower efficiency in health care, up to a threshold IT level (2.722) at which the impact of IT on hospital efficiency becomes positive.

The length of stay has a negative and significant impact on efficiency. On the other hand, the occupancy rate and the revenue per patient per day have a positive and significant effect on efficiency. With respect to size, medium sized hospitals appear less efficient vis-à-vis small hospitals. In columns (2) and (4), the IT variable (IT_pc) covers only IT expenses for direct patient care (and excludes expenses for salary of IT employees as well as expenses for other services as consulting, supplies, etc.). Results obtained in columns (1) and (3) are confirmed: namely IT and efficiency convey a U-shaped relationship. Finally in Table 5 we present the results of estimating Eqs. (3) And testing for Proposition 3. For comparative purposes we also Present both results from a bootstrap Tobit and a bootstrap truncated regression. The results in columns (1) and (3), in which IT is measured as total expenses in IT, and in columns (2) and (4), in which the IT variable (IT_pc) covers

Table 4
U-shaped relationship between IT and Efficiency

U-shaped relationship between IT and Efficiency.				
Dependent variable	*Bootstrap tobit*		*Bootstrap truncated regression*	
	Efficiency (1)	*Efficiency (2)*	*Efficiency (3)*	*Efficiency (4)*
IT (in logs)	0.083***		0.049***	
	(0.030)		(0.012)	
IT2 (in logs)	0.016**		0.009***	
	(0.007)	0.046***	(0.003)	0.030***
IT_pc (in logs)	–		–	
		(0.017)		(0.008)
IT_pc2 (in logs)	–	0.016**	–	0.009***
	0.017	(0.007)		(0.003)
CMI		0.025	0.023	0.018
	(0.045)	(0.046)	(0.029)	(0.031)
Urban	0.015	0.016	0.021	0.022
	(0.021)	(0.021)	(0.014)	(0.015)
Teaching	0.007	0.005	0.004	0.004
	(0.019)	(0.018)	(0.013)	(0.013)
rel_avg wage	0.055***	0.054***	0.032***	0.032***
	(0.018)	(0.018)	(0.011)	(0.011)
occupancy_rate	0.002***	0.002***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
revenue_ppd	0.021***	0.019***	0.010***	0.009***
	(0.004)	(0.004)	(0.002)	(0.002)
Calos	0.039**	0.033**	0.013	0.011
	(0.016)	(0.017)	(0.010)	(0.011)
Medium	0.073**	0.085**	0.043*	0.049**
	(0.037)	(0.035)	(0.022)	(0.022)
Large	0.050	0.073*	0.023	0.035
	(0.043)	(0.040)	(0.025)	(0.024)
Year_2005	0.031**	0.033**	0.019**	0.020**
	(0.014)	(0.014)	(0.009)	(0.009)
Sigma	0.121***	0.122***	0.088***	0.088***
	(0.006)	(0.006)	(0.003)	(0.003)
Log likelihood	69.387	65.567	378.419	376.340
Wald v2	152.634***	155.994***	140.421***	150.747***

Notes: The dependent variable is the bootstrap DEA efûciency score (efficiency) from the ûrst stage. Bootstrapped standard errors are in parentheses. 2000 bootstrapping replications were used. Constant is omitted to conserve space.

*Denotes significance at 10% level.

**Denotes significance at 5% level.

***Denotes significance at 1% level.

only IT expenses for direct patient care, confirm the result obtained previously; that the relationship between IT and efficiency has a U-shaped form even after controlling for quality. Additionally, the results show that the relationship between quality and efficiency is linear, but only positive for the case of complications. Controlling for quality in the IT-efficiency relationship implies that the threshold level at which the impact of IT on hospital efficiency becomes positive is lower.

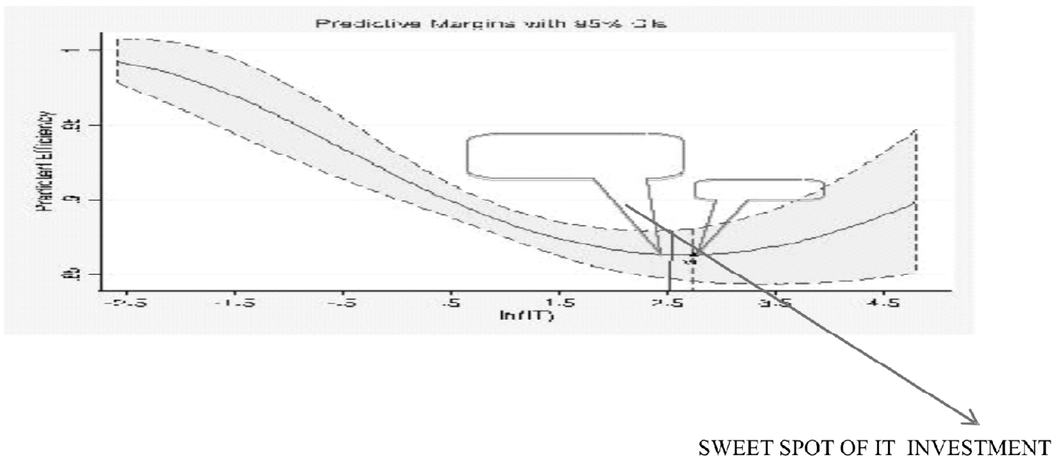

Figure 1: U-shaped relationship between IT and health care efficiency.

FINDINGS

Our estimation results indicate that IT has a direct impact on quality (Proposition 1); IT impacts efficiency in a U-shaped form (Proposition 2); and IT and quality positively impact efficiency *but after a threshold level of IT investment have been surpassed (Proposition 3).* Proposition 3 complements Proposition 1 and Proposition 2 and suggests that IT's impact on efficiency is moderated by quality. The conventional wisdom is that efficiency manifests before quality because process changes generally seek to simplify steps and lower costs. We find that although IT directly influences quality (in terms of mortality); its impact on efficiency is moderated by quality (in terms of complications). Therefore, quality appears central to the investment of IT in hospitals. Our findings suggest that IT investment's influence on increasing quality is not at the cost of efficiency. In other words, hospitals can achieve 'have it all' with both higher efficiency and higher quality. Our findings shed further light on how IT influences quality and efficiency. We find that the impact of IT investment on efficiency is non-linear. Indeed, there appears to be a '**sweet spot'** at which efficiency is optimal. This suggests that IT's contribution to efficiency, for example through automation, reaches diminishing returns, a finding that is of practical relevance to hospital administrators. Business process redesign (BPR), aiming on quality improvements, has also been examined in IT business value research (Grover *et al.,* 1998). Our findings shed further light on previous findings that found That higher levels of IT investment are associated with reduced operating expenses in acute care hospitals in the but only after hospitals have reached a threshold level of investment (Beard *et al.,* 2007).

This study revealed that at lower initial levels of IT investment, operating costs increased with incremental investment and that hospitals with higher IT investments tend to have a lower mortality rate (as a measure of quality).

Similarly, Menon, Yaylacicegi, and Cezar (2009) developed a model to assess the longitudinal impact of two types of IT investment on hospital output and medical labor productivity. They found that clinical IT lags improved hospital output in the short run and administrative IT was negatively associated with organizational performance in the short run but positively associated with these performance measures over the long run. More recently, a report from Fitch Ratings (Lewis, 2011) concluded that investments in health care IT and improved clinical quality measures had a significant impact on a hospital's operating performance. In our findings, while IT's influence on quality is significant on hospital mortality, we did not find a significant relationship with hospital ''complications'', our second measure of quality Our findings shed light upon how IT investments influence quality and operational efficiency among hospitals. We find that IT investments lead to higher service quality and also play moderating role in achieving operational efficiency. IT investments improve operational efficiency but up to a certain point.

LIMITATIONS AND SCOPE FOR FURTHER RESEARCH

There is a sizable literature investigating the business value of IT for different industries. However, the business value of IT in health care is still to be fully investigated (Devaraj *et al.,* 2013;Haddad *et al.,* 2014). Our paper contributes to ongoing investigations of IT business value in health care by answering two important research questions ''i) Can hospitals improve their operational efficiency as well as health care quality by investments in information systems?'', and ''ii) What is the optimal balance of efficiency and quality relative to IT investment? In other words, ''What is the 'sweet spot' of IT investment at which both operational efficiency and service quality are maximized?'' We identified the interplay of efficiency and quality and the characteristics of the hospitals that can better take advantage of their IT investments. Several researchers argue in order to understand the effects of technology on performance, the technology's process-level impacts need to be examined (Brynjolfsson & Hitt, 1996; Rai, Patnayakuni,& Seth, 2006; Sambamurthy, Bharadwaj, & Grover, 2003). Process level impacts provide a means for understanding the underlying mechanisms through which the impacts of IT are causally related to performance. However, our macro production function view contributes to the existing literature because it is important for hospital administrators to understand the overall impact of IT investment and its contribution to performance. These decisions influence the allocation of funding. Previous IT value research has focused on how to extract the most from information systems ''after'' this allocation has been made. In addition to seeking answers to the above research questions, this paper contributes to the literature with an alternative methodological approach based upon a two-stage double bootstrap data envelopment analysis (DEA), in line with Simar and Wilson (2007). Despite the popularity of DEA to measure efficiency in hospitals, few studies have used bootstrapping to account for measurement errors in estimates, the exceptions being Staat (2006) and Araújo *et al*. (2014), among others.

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