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Measurement of IT-Enabled Production Capability and Benchmarking of Public Hospitals: Data Envelopment Analysis

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ABSTRACT

Given the dearth of studies on Healthcare Information Systems in public hospitals, the present study proposes a conceptual framework for measuring Information Technology (IT)-enabled production capability by factoring relative efficiencies of IT and firm-specific resources. We employed cross-sectional data analysis using an output-oriented, variable return-to-scale model, viz., Data Envelopment Analysis (DEA). The study empirically tested the conceptual model based on the secondary data obtained from 31 Tamil Nadu district headquarters public hospitals in India. The results identified only two hospitals that are technically efficient in terms of IT-enabled production capability. The study findings have implications for strengthening health management information systems (HMIS) in public hospitals by deploying optimum IT infrastructure elements. Further, hospital administrators can utilize the study to measure the IT-enabled production capability of a public hospital to undertake benchmarking exercises. The conceptual framework with the DEA model is the earliest attempt to measure IT capability objectively in the health services industry.

Keywords: Data Envelopment Analysis (DEA), Public Hospitals, IT Efficiency, Benchmarking

Ⅰ. Introduction

Judicious investments in implementing information technology (IT) in hospitals have been warranted to improve patient safety (Salahuddin et al., 2020), medical outcomes (Kruse and Beane, 2018), efficiency (Şahin et al., 2021), quality, and reduce costs (Buntin et al., 2011; Chaudhry et al., 2006; Goldzweig et al., 2009). IT's catalyzing role in complementing (Zhu, 2004a) hospitals' performance has evolved vastly. It has penetrated deeply from its early use as a means to process patient billing (Menon et al., 2000a) to the automation of clinical records and operational management for effective clinical and

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operational decision-making (Amarasingham et al., 2019). Many public and private hospitals have been formulating and implementing IT-enabled initiatives to strengthen the delivery of healthcare services (Alolayyan et al., 2020).

Despite high growth in healthcare information technology (HIT) investments during the last decade, studies examining its beneficial impact on hospital performance remain inconclusive (Bui et al., 2018). The "IT Productivity Paradox" (Brynjolfsson and Yang, 1996) owes its origin to the disconnect between IT resources and firm-specific resources and its discernible impact on organizational performance. Researchers postulated that one of the significant reasons for this paradox could be the lack of proper measures for conducting the efficiency analysis (Subriadi et al., 2013) across all industries, including more specifically in the healthcare services industry (Bui et al., 2018).

Although studies have established that IT spending in hospitals positively impacted medical outcomes in terms of efficiency and effectiveness (Kruse and Beane, 2018) in private hospitals, there is scarce literature on IT management in public hospitals. In a developing country like India, where there are insufficient hospital workforce and infrastructure (Bajpai, 2014), it has become imperative for the healthcare sector to launch digital transformation programs. Government bodies are investing heavily in IT infrastructure resources to enhance the deficit of public healthcare resources, perceiving it as a capability that can reap rich dividends for the industry (Dahiya and Mathew, 2018). HIT investments and performances are rarely factored in a while calculating firm-specific capabilities (Menon et al., 2000b). Developing an integrative conceptual framework to measure hospital-specific resources (Kohl et al., 2019), IT infrastructure resources (Dahiya and Mathew, 2018), and a hospital's overall efficiency is necessitated (Brinch et al., 2020; Ganbold et al., 2021; Mikalef et al., 2020; Thompson et al., 2020) because the hospital-specific and IT capabilities are different but complemented (Zhu, 2004b).

The extant literature on IT resources (Ravichandran and Lertwongsatien, 2005) has not adequately examined the influence of IT capability on firm performance comprising organization-specific capabilities (Aral and Weill, 2007; Melville et al., 2004; Mithas et al., 2008). It was observed that IT's successful application is often accompanied by complementary organizational capabilities and other firm-specific practices (Barua et al., 1996; Besson and Rowe, 2012; Dahiya and Mathew, 2016). A study by Ayabakan, Bardhan and Zheng (2017) analyzed the effects of IT on manufacturing firm performance and found that firms can realize the full potential of IT by complementing it with organizational capabilities. They proposed a new IT-enabled production capability to measure manufacturing performance using a mix of IT and non-IT resources. IT-enabled healthcare delivery mechanisms such as remote virtual consulting and telemedicine require close collaboration between human resources (such as physicians, paramedics, and nurses) and the IT infrastructure resources such as efficient and sufficient computer systems, good broadband network, backup storage servers, and digitally savvy users, etc. (Findik and Tansel, 2015). However, recent efficiency studies conducted used only the traditional indicators to measure hospital performance (Cinaroglu, 2021; Şahin et al., 2021), where the adoption of IT complemented the firm-specific resources (Findik and Tansel, 2015). A few studies leveraged IT resources to focus on the firm efficiency in the manufacturing sector (Ayabakan et al., 2017). Studies combining hospital efficiency with IT efficiency are currently lacking in the literature.

Therefore, it becomes imperative to conceptualize a framework to measure IT-enabled production capability for a hospital. As part of this study, the following research questions were formulated:

RQ1. What factors define the IT-enabled production capability of a hospital?
RQ2. How to measure the IT efficiency of hospitals?

The paper is organized as follows. A literature review is provided in the next section. The results of IT TE, the hospital's specific TE, and an IT-enabled production capability are also presented.

Ⅱ. Literature Review

This section reviews the existing literature on IT, its impact on firm performance, and the effect of health IT (HIT) on hospital performance.

2.1. IT and Firm Performance

<Table 1> summarizes the seminal studies that examined the importance of organizational capabilities in studying the impact of IT on performance or productivity.

A Survey of extant research highlighted the burgeoning academic interest in analyzing the impact of IT on firm performance (Ayabakan et al., 2017).

<Table 1> Significant studies on IT and Firm Performance

Author	Key Focus	Method	Variables
Amit and Schoemaker (1993)	Strategic Assets, Organizational Rents	Conceptual Analysis	Firm (resources, capabilities, strategic assets), strategic industry factors
Venkatraman (1994)	IT-Enabled Business Transformation	Conceptual Analysis	Localized exploitation, internal integration (Technological enablers, technological inhibitors, organizational enablers, organizational inhibitors), business process redesign, business network redesign, business scope redefinition
Pavlou (2002)	IT-Enabled Dynamic Capabilities	Partial Least Squares	IT competence, resource configurability, trust, knowledgebase, environmental turbulence, competitive advantage
Melville et al. (2004)	IT and Organizational Performance	Conceptual Analysis	IT Resources, complementary organizational resources, business process, business process performance, organizational performance, industry characteristics, trading partner resources
Ravichandran and Lertwongsatien (2005)	Is Resources and Capabilities on Firm Performance	Partial Least Squares	IS Resources (IS Human Capital, IT Infrastructure Flexibility, IS Partnership Quality), IS Capabilities, IS Support for Core Competencies, Firm Performance
Banker et al. (2006)	Plant Information System, Manufacturing Capabilities, Plant Performance.	Exploratory Factor Analysis, Structural Equation Modelling, Regression	Just-in-time manufacturing, customer & supplier participation programs, resource planning systems, operations management systems, electronic data interchange, quality, time to market, and efficiency

<Table 1> Significant studies on IT and Firm Performance(Cont.)

Author	Key Focus	Method	Variables
Aral and Weill (2007)	IT Assets, Organization Capabilities, Firm Performance	Confirmatory Factor Analysis	IT Resources (IT Assets, IT Capabilities)
Albadvi et al. (2007)	IT on Firm Performance	ANOVA	IT applications (Organisation infrastructures, IT on the business process), intervening variables, and performance
Mithas et al. (2008)	IT Infrastructure Capability and Firm Performance	Baldrige Quality Framework	3 Dynamic capabilities (customer management capability, process management capability, and performance management capability) as the mediator between IT infrastructure capability and firm performance
Seol et al. (2008)	IT on Organizational Efficiency	Integrated DEA and Decision Tree	Public servants, Budget, Handling of civil-request, reports (case)
Tavana et al. (2009)	IT on Organizational Efficiency	Two-stage DEA model	IT budget, Fuel costs, number of employees
Yu et al. (2010)	Performance of Information System	DEA and Balance Score care	IS Performance, Organization functions (finance, customer, internal processes, learning, and growth)
Bharadwaj et al. (2013)	Digital Business Strategy (Business Strategy and IT Strategy)	Conceptual analysis	Scope, scale, speed of digital business strategy, and source of business value creation
Drnevich and Croson (2013)	Information Technology and Business-Level Strategy	Conceptual analysis	IT investment, IT resources, capabilities, firm performance, value
Dahiya and Mathew (2018)	IT Infrastructure Capability, E-Government Performance	Structural equation modeling	Infrastructure, transactional, informational, reliability, flexibility, scalability, functionality, connectivity, competencies, practices, quality of service, quality of governance
Ayabakan et al. (2017)	IT-Enabled Capability on Firm Performance	Data Envelopment Analysis	Production Capability (IT and non-IT resources); Plant Performance (Gross Margin)

One facet of Firm Performance literature has focused on the measurement of firm performance using firm-specific resources and firm-specific capabilities (Schoemaker and Amit, 1993), and another facet stream of literature focused on enhancing firm performance (Aral and Weill, 2007) by using IT resource (Albadvi et al., 2007), IT capabilities (Dahiya and Mathew, 2016), IT strategy (Ali et al., 2016) and IT performance (Yu et al., 2020). Few studies have researched "IT-enabled capability, whereas (Pavlou, 2002) studied IT-enabled dynamic capabilities that focus on competitive advantage. Ayabakan et al. (2017) studied the IT-enabled production capability of a manufacturing firm. These studies did not consider the output derived from IT while measuring the IT-enabled capability.

2.2. HIT Impact on Hospital Performance

Most hospitals are at the threshold of exploiting the maximum benefits of HIT (Gareth et al., 2019). A related question pertains to the adequacy of HIT

resources, given that the efficiency of a system depends on the efficiency of resources. <Table 2> summarizes the significant studies on HIT impact and hospital performance from resources and capabilities perspectives.

From the literature review, it can be inferred that researchers mainly focused on the effect of HIT investment and hospital productivity (Das et al., 2011; Devaraj and Kohli, 2000). Devaraj and Kohli (2000) opine that investments in IT capital and labor do not directly impact overall hospital productivity. However, it improves the organization's processes and enhances customer satisfaction. Using the Stochastic Production frontier method, the study measured hospital productivity with IT and organizational inputs. Devaraj and Kohli (2003) measured

<Table 2> Significant Studies on HIT Impact and Hospital Performance

Author	Key Focus	Method	Variables
Devaraj and Kohli (2000)	HIT Investment in Hospital Productivity	Regression	Hospital profitability, quality, technology investment (IT labor, capital, support), business process reengineering (BPR), service index, labor intensity, Medicare, Medicaid, income, outpatient mix
Menon et al. (2000b)	HIT and Hospital Productivity	Stochastic Production Frontier, Cobb – Douglas Function	Labor and Capital: (Medical Labor and IT Labor) (Medical IT capital, medical capital, IT capital), available beds, adjusted patient days, operating revenues, operating cost, operating income
Lee and Wan (2003)	HIT and Hospital Productivity	Descriptive, DEA, and LISREL (Linear Structural RELationship	Output (Admissions, outpatients); Input (Services, Employees, size (bed, staff))
Devaraj and Kohli (2003)	IT System Usage and Hospital Performance	Regression, Time – Series Analysis	Technology usage (Reports, processing time, number of records accessed), Hospital Performance (Mortality, revenue per admission, revenue per day)
Koppel et al. (2005)	HIT Usage and Its Performance	Qualitative and Quantitative	Computerized provider order entry (CPOE), medication errors
Menachemi et al. (2006)	IT Utilization and Hospital Financial Performance	Regression	Clinical IT, Administrative IT, Strategic IT, Demographic variables, return on assets, cash flow, operating margin, case mix, and bed size.
Linder et al. (2007)	HIT Usage and Hospital Quality Performance	Regression	Electronic Health Record (EHR) use, Quality indicators: (they are medical management of common diseases, recommended antibiotic use, preventive counseling, screening tests, and potentially inappropriate prescribing in the elderly patient).
Daskalkis et al. (2008)	HIT on Hospital Productivity	Data Envelopment Analysis (DEA)	Inputs (network and software infrastructure) Outputs (interoperability, data exchange mechanism, and ability to support open standard)
Kazley and Ozcan (2009)	HIT on Hospital Productivity	DEA and Window Analysis	Electronic Medical Record (EMR) Use, Teaching status, Non - Profit Ownership, Public Ownership, System Membership, Beds set up and Staffed

<Table 2> Significant Studies on HIT Impact and Hospital Performance(Cont.)

Author	Key Focus	Method	Variables
DesRoches et al. (2010)	HIT Usage, Hospital Quality, and Efficiency	Multivariable Models	EHR use, the process of care, mortality rate, length of stay, readmission rate, inpatient cost
McCullough et al. (2010)	HIT Usage and Hospital Quality	Multivariate Regression	CPOE, EHR use, the process of care measure, academic and non-academic hospitals
Queenan et al. (2011)	IT Infrastructure, HIT Use, and Healthcare Quality	Ordinary Least Square Regression and Hierarchical Regression	No: of hospitals, No: of staffed beds, Hospital age, Location: urban/rural, Academic status: academic/non-academic, CPOE use, IT infrastructure, Patient satisfaction.
Das et al. (2011)	Health IT Investment in Hospital Productivity	Ordinary Least Square Regression	IT Capital Investments (patient management IT, transactional support IT, communications IT, and administrative IT); Hospital Performance (Opening Costs, Medical Labor Productivity, Administrative Labor Productivity)
Angst et al. (2012)	IT in Communication-Based Transactions	Structural Equation Modeling and SMART PLS	IT Infrastructure (Administrative and cardiology), process (interpersonal care, technical protocols of care), outcome (mortality, hospital rating, patient loyalty)
Lee, McCullough, and Town (2013)	Health IT on Hospital Productivity	Cobb-Douglas Production Function	IT investment, IT Capital, IT labor, non‐IT capital, and labor
Lee, Wan, and Kwon (2013)	Organizational Factors, Cost, and Hospital Information System (IT capability)	Structural Equation Modelling	Hospital functions (administration, management, and clinical); Total hospital expense
Salge et al. (2015)	Hospital is Investment Decision	Regression	Is investment intensity, Performance relative to aspirations, Financial slack, Regulative legitimacy, Size, R&D intensity, Case-mix, Caseload, Foundation trust status, Regional overcapacity, population health status, rurality
Williams et al. (2016)	Health IT on Hospital Performance	(DEA), Automatic Interaction Detector Analysis (AID) and Decision Tree Regression (DTreg)	Full-time equivalents, hospital size, technology inputs (personal health records, electronic medical records, computerized physician order entry systems, electronic access to diagnostic results); measures of quality, hospital readmission, and mortality rate
Kaneko et al. (2018)	Health IT on Hospital Productivity	Logistic Regression Model	EMR Implementation Stage (Late Adopter, Follower, Early Adopter); Labor Productivity, Multifactor Productivity

the actual usage of IT in hospitals by studying the IT impact on hospital performance - rather than using investment. They added organization variables as control variables. However, Menachemi et al. (2006) indicated that the relationship between actual IT use and financial outcomes would yield more substantial justification than just using IT applications' availability as a measure. Das et al. (2011) studied the causal relationship between IT capital investment and Hospital Performance and emphasized the need to check the IT efficiency of the hospital. They found that 210% of investment in

health IT inputs has contributed to merely a 6% increase in value. Salge et al. (2015) highlighted how the initial resource allocation stage impacts IT investment decisions. Lee, Wan, and Kwon (2013) identified organizational factors that affected the adoption of information systems in hospitals. Williams et al. (2016) studied the effect of IT on hospital performance using outputs obtained from IT. They found that organizational efficiency is a precursor to implementing any technological innovation. (Agarwal et al., 2017; Kaneko et al., 2018; Kazley and Ozcan, 2009) studied the utilization of EHR and EMR in hospitals and their role in fostering productivity. While various factors impacting hospital efficiency have been studied, the authors did not consider information system (IS) efficiency. Notwithstanding the above studies in analyzing the impact of health IT on hospital productivity, the effects of IT on a firm's efficiency need to be examined in an integrated manner. Towards addressing the gaps in the literature, a theoretical framework is proposed in the following section while considering both firm-specific capability and IT capability.

Ⅲ. Theoretical Framework Development

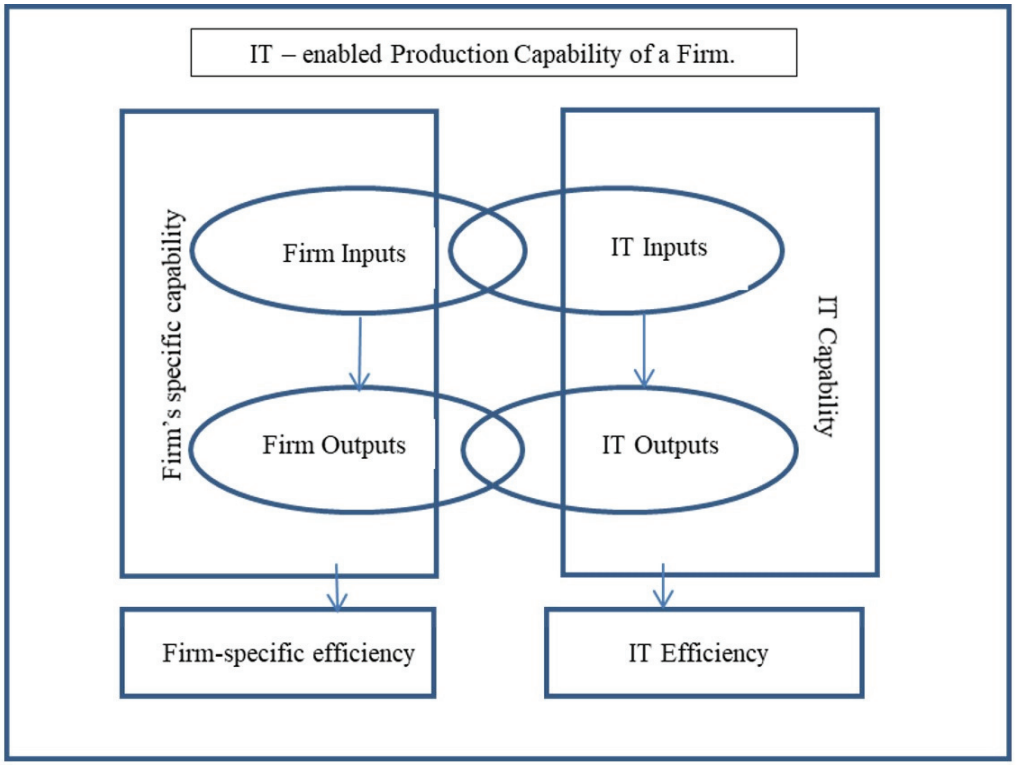
A firm-specific capability is defined as a set of firm-specific input and output variables measuring firm-specific functionalities (Shao and Lin, 2002). IT capability is defined as the "IT-based resources in combination or co-present with other firm-specific resources and capabilities" (Bharadwaj, 2000). There is a distinction between firm-specific capability and IT capability – the former indicates the firm's core resources that are specific in delivering the service to its customers, and the latter is the complementing resources that enable core resources to increase their overall performance.

Given the level of technology adoption in the healthcare sector, it is essential to have an integrated view of how firm-specific capability and IT capability contribute to firm performance. The present study builds on (Ayabakan et al., 2017), who initially proposed the concept of "IT-enabled Production Capability." A firm is an IT-enabled production capable (<Figure 1>) if it is efficient both in terms of its specific capability and IT capability (Melville et al., 2004; Ravichandran and Lertwongsatien, 2005). These measures capture IT infrastructure and firm-specific resources' characteristics to help build a sufficient allocation of resources for IT-enabled production capability.

One can determine the extent of IT and hospital-specific resource utilization in the healthcare sector by estimating the production frontier while factoring in hospital services. The healthcare facility is a production capability where hospital-specific inputs (doctors, nurses, number of beds, etc.) are transformed into different hospital outputs (inpatient, outpatient, delivery cases, surgery volume, etc.). IT resource inputs (computers, printers, UPS, etc.) and outputs (patient data records, imaging files, etc.) enable the hospital's performance by transforming the hospital-specific inputs into hospital-specific outputs. Therefore, hospital-specific and IT efficiency resources are independent of each other and are neither substitutable nor transformable logically, according to (Barnum et al., 2011).

Ⅳ. Methodology

We employ a two-stage non - parametric frontier DEA (Data Envelopment Analysis) method to ad-



<Figure 1> Theoretical Framework of IT-enabled Production Capability of a Firm

dress the identified research gap. Data Envelopment Analysis (DEA) methodology introduced by A. Charnes, W. W. Cooper, and Rhodes in 1978 is the most non-parametric approach. It analyses the relative efficiency score of the decision-making unit (DMU). Using the available resources of the DMU as an input variable, it considers the impact of the process in that DMU as the output variable. These variables play a significant role in analyzing the efficiency of the DMUs (Fazria and Dhamanti, 2021). In this study, hospitals are considered as DMU.

In this two-stage DEA approach, in the first stage, we computed the relative technical efficiency of the hospital-specific capability. In the second stage, we calculated the relative technical efficiency of the hospital's IT capability.

4.1. Data Collection

Our study focuses on the Health Management Information System (HMIS) effect in India's District Headquarters hospitals in Tamil Nadu. The state is considered a front-runner in India based on vital health indicators in India. It is also recognized as a role model for the rest of the country, especially in maternal and child care and IT implementation. HMIS is an initiative deployed by the Government of India through National Health Policy 2002 and Pradhan Mantri Swasthya Suraksha Yojana ("National Health Policy, 2017") to improve public efficiency in hospitals. Its main objective was "to access the right information and automation of workflow" and enable the health workforce to concentrate more on

patient care. A decentralized Healthcare Information System was deployed across the Indian states and aligned with the centralized healthcare web portal (Pandey et al., 2010). HMIS, implemented in Tamil Nadu State by Tamil Nadu Health System Project (TNHSP) in 2005, comprises four components: hospital management system, management information system, college management system, and university automation system (Natarajan et al., 2013).

Tamil Nadu had district-level hospitals in all its 31 districts (as of 2017). HMIS of the state has centralized web-based software, running through hassle-free 2Mbps leased Tamil Nadu State Wide Area Network connectivity and a redundant 2Mbps Broadband connectivity, which terminates at each public hospital. An automatic switchover has also been placed to aid at times of connectivity failure. The data center houses the entire database of the centralized web server with an uninterrupted power supply. Besides, the hospitals are backed up by UPS for 2 hours in case of sudden power failure (Natarajan et al., 2013).

The measures employed in the study represent the general areas of direct services that hospitals provide to patients. Attempts were made to incorporate a reasonably comprehensive list of inputs and outputs to measure both hospital's specific technical and IT technical efficiency. It is estimated that after implementing the HMIS, However, DEA operates more powerfully when the number of DMUs exceeds the number of the combined total inputs and outputs by at least twice chosen for the study (Drake and Howcroft, 1994). As the district's population is highly heterogeneous, we considered all the people-based input and output variables per 1000 population to convert them into homogenous DMUs and normalized the resources.

This study measured hospital-specific technical efficiency, the hospital-specific capability in the first stage, and hospital IT technical efficiency, the hospital's IT capability in the second stage. The input and output variables used to measure the hospital's specific technical and IT technical efficiency are given in <Table 3> and <Table 5>, respectively. The choice of input and output variables to measure hospi-

<Table 3> Input and Output Variables used in DEA Model Analysis of Hospital-specific Technical Efficiency

Factors	Variables	Abbreviation	Description
Inputs	No: of Doctors per 1000 Population	I_d	A total number of full-time employed doctors, including specialists per 1000 population.
	No: of Nurses per 1000 Population	I_n	Total number of full-time employed nurses per 1000 population
	No: of Beds per 1000 Population	I_b	Total number of beds in the hospital per 1000 population
Outputs	No: of IP per 1000 per Year	O_ip	Average inpatients per year, including emergency cases and medico-legal cases per the year 1000 population
	No: of OP per 1000 per Year	O_op	Average outpatients per year per 1000 population
	No: of Deliveries per 1000 per Year (Normal + C-section)	O_de	The average number of c-section and regular deliveries conducted per year per 1000 population
	No: of Surgeries per 1000 per Year (Major + Minor)	O_s	The average number of minor and major surgeries performed in a year per 1000 population

tal-specific efficiency is similar to the study (Al-Shammari, 1999).

We considered several input and output variables drawn from the related literature (Daskalkis et al., 2008; Devaraj and Kohli, 2003) and got the same validated by healthcare experts.

Ⅴ. Results and Discussion

The efficiency scores were computed using DEAP v2.1 software. <Table 4> and <Table 6> provide the 31 DMUs, input, and output variables used in the study. We used output-oriented, variable re-

<Table 4> Hospital Specific Efficiency Variables of 31 DMU (2017)

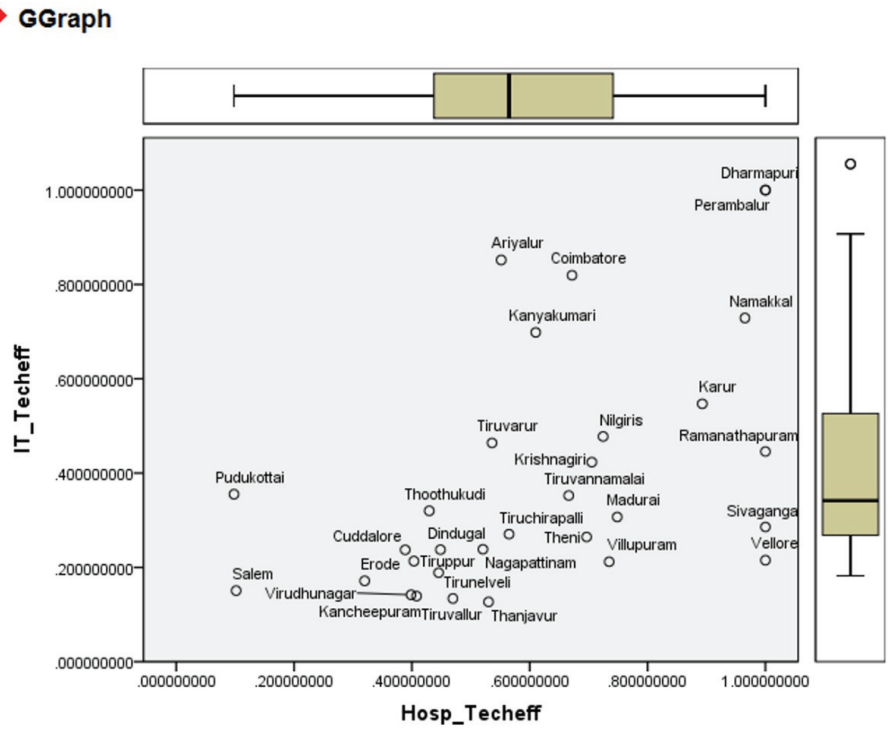
DMU Name	O_op	O_ip	O_de	O_s	I_d	I_n	I_b
Ariyalur	751.31	25.95	4.53	16.93	0.09	0.09	0.56
Coimbatore	226.24	7.73	1.23	3.11	0.01	0.02	0.18
Cuddalore	446.65	25.53	3.90	5.30	0.05	0.09	0.45
Dharmapuri	344.12	7.35	0.90	1.43	0.02	0.01	0.15
Dindugal	637.50	29.79	4.85	12.20	0.06	0.09	0.59
Erode	433.73	28.75	2.44	5.89	0.06	0.08	0.54
Kancheepuram	278.74	14.19	1.76	3.19	0.03	0.05	0.27
Kanyakumari	247.27	6.35	1.12	5.64	0.03	0.03	0.16
Karur	234.37	8.20	0.79	10.09	0.02	0.04	0.19
Krishnagiri	487.72	27.03	5.11	9.63	0.06	0.08	0.29
Madurai	172.40	5.53	1.63	3.04	0.01	0.02	0.08
Nagapattinam	441.41	23.43	1.96	3.11	0.03	0.11	0.55
Namakkal	448.80	29.20	1.59	4.27	0.02	0.03	0.17
Perambalur	1106.67	76.02	12.86	33.44	0.06	0.12	0.57
Pudukottai	248.27	11.08	2.26	2.97	0.21	0.26	0.94
Ramanathapuram	563.07	40.50	5.10	11.45	0.02	0.03	0.20
Salem	165.54	7.14	0.96	1.66	0.07	0.13	1.01
Sivaganga	263.97	12.16	3.41	3.28	0.01	0.02	0.15
Thanjavur	277.34	18.73	3.07	5.09	0.02	0.05	0.33
The Nilgiris	325.76	21.41	2.84	4.97	0.02	0.05	0.43
Theni	418.17	11.57	1.90	1.68	0.02	0.07	0.47
Thoothukudi	334.10	17.59	2.89	4.48	0.04	0.06	0.28
Tiruchirapalli	168.83	5.58	1.26	0.79	0.01	0.02	0.11
Tirunelveli	200.99	10.47	1.33	2.06	0.02	0.03	0.16
Tiruppur	469.61	20.68	3.89	5.61	0.05	0.07	0.42
Tiruvallur	204.11	13.36	2.26	4.78	0.03	0.04	0.19
Tiruvannamalai	184.73	9.26	0.70	1.74	0.01	0.02	0.10
Tiruvarur	382.16	15.26	2.21	4.05	0.03	0.06	0.31
Vellore	268.57	4.19	0.38	3.34	0.01	0.01	0.15
Villupuram	172.87	11.31	1.94	3.62	0.01	0.01	0.11
Virudhunagar	266.86	12.05	3.58	4.80	0.04	0.07	0.46

<Table 5> Input and Output Variables used in DEA Model Analysis of Hospital Efficiency

	Variables	Abbreviations	Descriptions
Inputs	No: of Systems (Computers)	i_c	Total number of computers functioning in the hospital
	No: of Printers	i_p	Total number of printers functioning in the hospital
	No: of UPS and Batteries	i_ub	Total number of UPS and batteries functioning in the hospital
	No: of Users (Doctors + Nurses)	i_u	Total number of computer users (doctors + nurses) functioning in the hospital
Outputs	No: of OP Records per 1000 per Year	O_opr	Number of OP (outpatient) records per 1000 per year
	No: of IP Records per 1000 per Year	O_ipr	Number of IP (inpatient) records per 1000 per year
	No: of Imaging Records per 1000 per Year (OP+IP)	O_imr	Number of Imaging records per 1000 per year (OP+IP)
	No: of Lab Records per 1000 per Year (OP+IP)	O_lr	Number of Lab records per 1000 per year (OP+IP)

turn-to-scale DEA analysis for the study. Output-oriented efficiency measurements are appropriate to find hospital productivity given the limited number of inputs - the number of doctors, nurses, beds, etc. Output – oriented models are considered in the public healthcare domain due to the scarcity of the health workforce and the unpredicted inflow of patients.

Using the above data, a hospital can be termed technically efficient if it utilizes all its resources optimally and if there is no scope for maximizing the



<Figure 2> G-Graph of IT Technical Efficiency and Hospital Technical Efficiency

<Table 6> IT Variables of 31 DMU (2017)

DMU Name	O_opr	O_ipr	O_imr	O_lr	I_c	I_p	I_ub	I_u
Ariyalur	751.3	25.95	38.67	1584.55	114	60	116	174
Coimbatore	226.24	7.73	8.16	141.47	196	95	10	291
Cuddalore	446.65	25.53	33.03	255.81	329	114	169	443
Dharmapuri	344.12	7.35	3.46	143.17	112	43	6	155
Dindugal	637.50	29.79	72.57	766.67	333	149	479	482
Erode	433.73	28.75	41.10	542.71	345	234	367	579
Kancheepuram	278.74	14.19	44.99	611.30	214	95	219	309
Kanyakumari	247.27	6.35	6.89	89.25	262	98	10	360
Karur	234.37	8.20	4.42	246.58	108	52	152	160
Krishnagiri	487.72	27.03	51.34	907.68	156	70	176	226
Madurai	172.40	5.53	16.23	256.37	178	80	230	258
Nagapattinam	441.41	23.43	15.22	224.48	259	131	293	390
Namakkal	448.80	29.20	37.68	360.55	255	100	296	355
Perambalur	1106.67	76.02	181.92	2871.22	88	46	123	134
Pudukottai	248.27	11.08	5.413	157.77	194	110	130	304
Ramanathapuram	563.07	40.50	55.70	396.00	263	118	138	381
Salem	165.54	7.14	8.84	184.03	274	122	288	396
Sivaganga	263.97	12.16	7.69	268.23	265	133	382	398
Thanjavur	277.34	18.73	24.21	323.10	304	160	446	464
Theni	325.76	21.41	16.51	215.65	164	85	188	249
The Nilgiris	418.17	11.57	34.87	661.92	198	75	166	273
Thoothukudi	334.10	17.59	24.92	376.45	232	104	341	336
Tiruchirapalli	168.83	5.58	6.65	90.64	259	127	355	386
Tirunelveli	200.99	10.47	13.61	283.89	328	128	270	456
Tiruppur	469.61	20.68	25.91	158.92	274	125	242	399
Tiruvallur	204.11	13.36	21.75	205.77	263	111	301	374
Tiruvannamalai	184.73	9.26	7.15	166.51	235	116	289	351
Tiruvarur	382.16	15.26	16.28	303.66	209	92	228	301
Vellore	268.57	4.19	7.87	253.09	366	167	305	533
Villupuram	172.87	11.31	9.87	172.77	301	147	243	448
Virudhunagar	266.86	12.05	27.19	214.81	270	113	334	383

<Table 7> Hospital-specific Efficiency and IT Efficiency

DMU Name	Hosp_eff	Efficient	IT _ eff	Efficient
Ariyalur	0.55		0.85	
Coimbatore	0.67		0.81	
Cuddalore	0.38		0.23	
Dharmapuri	1	Yes	1	Yes
Dindugal	0.44		0.23	
Erode	0.31		0.17	
Kancheepuram	0.40		0.13	
Kanyakumari	0.61		0.69	
Karur	0.89		0.54	
Krishnagiri	0.70		0.42	
Madurai	0.74		0.30	
Nagapattinam	0.52		0.23	
Namakkal	0.96		0.72	
Perambalur	1	Yes	1	Yes
Pudukottai	0.09		0.35	
Ramanathapuram	1	Yes	0.44	
Salem	0.10		0.15	
Sivaganga	1	Yes	0.28	
Thanjavur	0.53		0.12	
The Nilgiris	0.72		0.26	
Theni	0.69		0.47	
Thoothukudi	0.42		0.31	
Tiruchirapalli	0.56		0.27	
Tirunelveli	0.44		0.18	
Tiruppur	0.40		0.23	
Tiruvallur	0.46		0.13	
Tiruvannamalai	0.66		0.35	
Tiruvarur	0.53		0.46	
Vellore	1	Yes	0.21	
Villupuram	0.73		0.21	
Virudhunagar	0.39		0.14	

output without altering the number of inputs used. Increasing the output is relatively complex in a public hospital, where the resources are not easily upgradable, even over prolonged periods. Notwithstanding the resource constraint, if a hospital can maximize the output with limited input resources, its TE score would be 1. On the other hand, a hospital is portrayed as inefficient if its scope of reducing the usage of some of the inputs exists without affecting the current output level. The TE score of such inefficient hospitals would be less than one.

<Table 7> shows the hospital-specific TE score of hospitals in Dharmapuri, Perambalur, Ramanathapuram, and Sivagangai districts in 2017 for the selected input and output. The IT TE of Dharmapuri and Perambalur was one, which means that among the 31 hospitals considered for the study, Dharmapuri and Perambalur districts have utilized the IT resources optimally. According to our IT-enabled productivity capability framework, a hospital is technically efficient if it optimally uses its specific IT resources to attain its goals. Therefore, a hospital is an IT-enabled production capability if it achieves "1" in hospital-specific and IT-specific TE. Our analysis found that hospitals in Dharmapuri and Perambalur were technically efficient in both hospital-specific and IT efficiency (<Figure 2>).

Keeping them as benchmark districts, we can measure the various inputs needed for other districts to satisfy the average output demand.

Ⅵ. Implications of the Study

The present study conceptualized the objective measurement methodology of IT-enabled production capability for a hospital, supported by an integrated theoretical perspective grounded in production theory and resource-based view theory. Combining firm-specific and IT capabilities to measure a hospital's IT-enabled production capability objectively is a novel attempt that adds a new dimension to the extant literature.

Administrators of hospitals can utilize the study findings to arrive at optimum quantities of infrastructure resources required for an IT-enabled production capability. In addition, we contribute to the IT management practice by establishing that both firm-specific and IT capability enhance firm performance.

Ⅶ. Conclusions

The present study contributes to the sparse literature by (i) developing an integrated framework to analyze the impact of health management information system capability on hospital performance and (ii) employing DEA with a unique set of input and output variables to benchmark public hospitals. Our study indicates that healthcare management information systems significantly impact the development of operational processes of the hospital's specific capabilities, which act as critical differentiators of hospital performance. Our results emphasized the integration of hospital-specific resources and IT resources as a possible path to enhance healthcare performance – i.e., hospitals need to strive for effective integration between hospital-specific core capability in the front-end and back-end IT infrastructure to reap the full benefits of HMIS implementation.

The present study has a few limitations, which we expect to be addressed in future research. First, like many previous studies, the absolute index was not considered in calculating TE to benchmark the hospitals. Second, patients' views were not included in the selection of outputs. In India (also in the

state of Tamil Nadu), a comprehensive database for assessing and collecting appropriate data associated with health outcomes is available, which measures quantitative outputs like the number of patient visits and revisits mortality, the number of surgeries performed, etc. However, qualitative outputs such as patient safety, quality of care, and satisfaction as outputs are not captured.

In addition, future research may focus on extending the proposed models to evaluate hospitals' IT-enabled production capability in other states and extend it to the private sector to perform a comparative analysis between IT-enabled private and public hospitals. Such studies will enrich the current research in MIS literature by factoring in IT-enabled production capability data. We fervently hope health policy planners and hospital administrators will utilize the integrated framework and the quantitative model to deploy scarce resources to improve the hospitals' overall performance.

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